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Nationwide Urban Runoff Program
Urban Runoff Control in Rapid City, South Dakota: Final Report

Black Hills Council of Governments
Rapid City, SD

Prepared for

Environmental Protection Agency, Washington, DC

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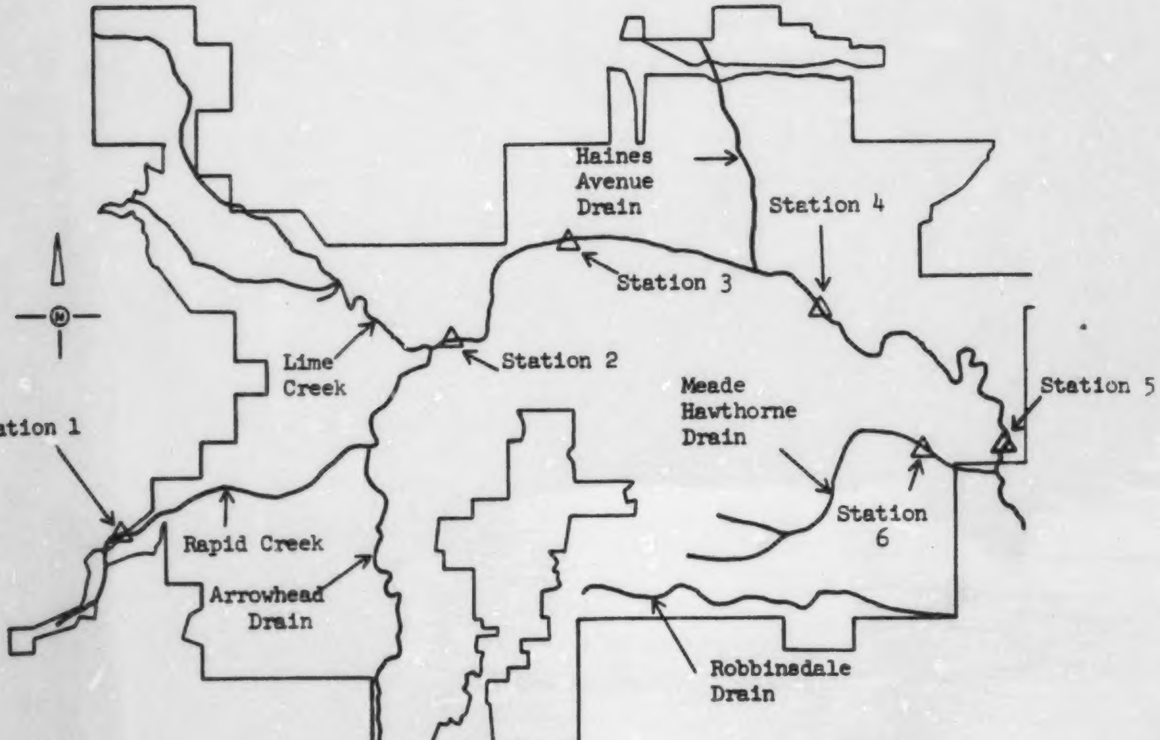
URBAN RUNOFF CONTROL IN RAPID CITY, SOUTH DAKOTA

FINAL REPORT

SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY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This project included monitoring and sampling in Rapid Creek to analyze and evaluate the effects of urban stormwater runoff on water quality, and snowmelt runoff effects. The correlation between increased concentrations of many pollutants and concentrations of suspended solids resulted in the recommendation that remedial measures should concentrate on reducing suspended solids loading to Rapid Creek.

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and

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Submitted on:

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1.a

ABSTRACT

Six water quality sampling stations were installed to monitor water quality changes in Rapid Creek resulting from urban stormwater runoff in the Rapid City, SD area. Five of the stations were in-stream locations on the creek while the sixth station was located on the drainage channel from a 2,000 acre watershed.

A total of 33 runoff events were monitored during 1980 to 1983, three of which were runoff from melting snow. Although some analyses of discrete samples were made, the norm was to composite the discrete samples in proportion to flow. Twenty complete data sets were obtained. Parameters measured included BOD, alkalinity, turbidity, pH, conductance, fecal coliforms, suspended solids, volatile suspended solids, total residue, total kjeldahl nitrogen, total and soluble phosphorus, ammonia, nitrate, sulfate, chloride, potassium, sodium, calcium, magnesium, and lead. All sampling sites were gaged by the USGS for flow, and sophisticated sampling equipment was used at four locations during 1981 and 1982. Priority pollutants were determined at selected locations on three occasions. Precipitation for sampled events ranged from 0.08" to 2.99" and the urban discharge ranged from near zero to about 470 acre-feet.

Concentrations of in-stream constituents varied widely throughout the study, with the majority of the constituents increasing in concentration at the downstream stations. Increases of several thousand percent were noted for many parameters from above to below the urban area. High lead and suspended solids increases were particularly noticeable. It was noted that the municipal wastewater treatment facility would require about three years to deposit as many suspended solids in Rapid Creek as were washed into the creek in one day during storm event No. 21.

Many of the parameters correlate well with suspended solids concentrations. Therefore, the recommendation was made that remedial measures should concentrate on reducing the suspended solids loading to Rapid Creek.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

EPA - United States Environmental Protection Agency

USGS - United States Geological Survey

NURP - National Urban Runoff Program

COD - Chemical Oxygen Demand

SS - Suspended Solids

VSS - Volatile Suspended Solids

NH_3-N - Ammonia-Nitrogen

TKN - Total Kjeldahl Nitrogen

EMC - Event Mean Concentration

UEMC - Undiluted Event Mean Concentration

r - Correlation coefficient

QA - Quality Assurance

μmho/cm - Micromhos per centimeter

BOD - Biochemical Oxygen Demand

Ult. BOD - Ultimate Biochemical Oxygen Demand

R^2 - Coefficient of Determination, same as r^2

SDSM&T - South Dakota School of Mines and Technology

$\bar{Q}$ - Mean flow

Q_{tf} - Mean flow - base flow

TP - Total phosphorus

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I. INTRODUCTION

Background

Although most of the nation's water clean up efforts have been directed at controlling water pollution from point sources, the concern for nonpoint source pollution has increased in the last decade. Section 208 of The Clean Water Act of 1972 and the Amendments of 1977 addressed the problem of nonpoint sources of pollution. Most 208 planning groups have recognized that nonpoint source pollution is a potential source of pollution to surface waters. The stormwater runoff from urban areas and its impact on receiving waters was the primary emphasis of the work reported herein.

Urban stormwater runoff is normally of short duration and may contain many polluting materials. During a storm event, urban runoff contributes heavy metals, suspended solids and other substances to watercourses. The sources of these pollutants are widely varied, ranging from animal refuse to construction sites. Pollutants can consist of, among other things, street litter, gas combustion products, ice control chemicals, rubber and metals lost from vehicles, decaying vegetation, fallout from industrial and residential combustion projects and chemicals applied to lawns and parks (1).

Urban runoff can be typically characterized as having: (a) solid concentrations equal to or greater than those of untreated sanitary wastewater; and (b) bacterial contamination of two to four orders of magnitude less than that of untreated sanitary wastewaters, but two to four orders of magnitude greater than concentrations considered safe for water contact activities (2). Historically, urban storm runoff has been described as very poor quality and does not dilute the concentrations already present in the receiving waters but instead increases many constituents dramatically. The water quality of over 75 percent of the surface waters in urban areas studied by the Council on Environmental Quality were found to be controlled by nonpoint source pollution (3). Without controlling nonpoint source pollution, the 1983 national goal of fishable and swimable waters cannot be achieved in part by many states.

Many streams in urban areas are not meeting water quality standards during storm events. Is it necessary to meet in-stream water quality standards during runoff events? Does urban runoff significantly affect the aquatic life of the stream? What kinds of toxic pollutants, if any, are entering the stream from urban runoff which may affect downstream beneficial uses such as domestic water supply, aquatic life, wildlife propagation or livestock watering? Should an urban area upgrade its wastewater treatment plant to meet 1983 goals (when in some cases costs may total in the millions of dollars) if urban runoff primarily controls downstream water quality? Should stream classifications be lessened to save costs of upgrading point sources if urban runoff discharges controls downstream water quality? These very real questions are being asked by many planning agencies throughout the nation whose responsibility is for developing the control plans.

A three year urban runoff program was conducted in Rapid City, South Dakota, from January 1980 to December 1982. The study was one of 28 national studies sponsored by the Environmental Protection Agency (EPA) under the National Urban Runoff Program (NURP). This effort will provide a comprehensive data base from many different regions in the country so that various management options to control urban runoff can be evaluated. The Rapid City study was to define the quality and quantity of urban discharges and the effects on in-stream quality.

Rapid Creek flows through Rapid City, South Dakota, and is the receiving watercourse of urban runoff. Rapid Creek has many beneficial uses of which the most stringent uses are classified as a cold-water permanent fish life propagation water and an immersion recreation water by the South Dakota Department of Water and Natural Resources (4).

The urban reach of Rapid Creek through Rapid City was excellent to study the effects of urban runoff on receiving waters. First, Rapid Creek is not affected by sanitary or industrial waste discharges, upstream from Rapid City and along the urban reach. In other words, there were no known point sources. Also, the stream is a small stream crossing a moderately sized urban area, with its upstream waters passing through a man made reservoir. This reservoir controls the discharge of the creek. Finally, the upper reaches of Rapid Creek pass through an undeveloped, forested area and are not affected by urban runoff until the creek reaches Rapid City.

Project Objectives

The Rapid City NURP was a cooperative effort among many agencies. These agencies are the:

U.S. Environmental Protection Agency
S.D. Department of Water and Natural Resources
Sixth District Council of Local Governments
City of Rapid City
South Dakota School of Mines and Technology
U.S. Geological Survey
S.D. Department of Game, Fish and Parks

Composite objectives of the project were:

A. Primary objectives were to:

1. characterize the impacts of urban runoff into Rapid Creek from both rainfall and snowmelt runoff; and
2. evaluate the effects of the runoff on a high quality, cold water fishery.

B. Secondary objectives were to:

1. assess the value of in-stream water quality standards as related to water quality during storm events; and
2. assess the impact of urban runoff on downstream beneficial uses.

The information reported within this report deals chiefly with objectives A1, B1 and B2. The evaluation of the fishery, objective A2, was primarily the responsibility of the SD Department of Game, Fish and Parks in conjunction with the SD Department of Water and Natural Resources.

Literature Summary of Urban Drainage

Urban stormwater runoff studies have shown that urban runoff can be a major source of stream pollution. Unfortunately, huge sums of money are sometimes being expended on constructing better secondary treatment plants while major sources such as urban stormwater runoff and combined sewer overflows go uncontrolled.

Precipitation falling on an urban area removes chemicals and suspended particles from the air. As the generated runoff flows across the ground it gathers dust, debris, litter, animal refuse, and toxic substances from littered, dirty streets, sidewalks and parking lots. In this section, some previous investigations on urban runoff will be briefly discussed. Few studies have been completed to date on assessing the water quality in small streams from nonpoint source pollutants, mainly the impact from urban storm runoff. Nonpoint sources are generally identified as having origins from agriculture, construction, mining, septic systems, silviculture and urban activities. All of the studies tend to be varied because of physical limitations and varying project objectives. Therefore, only those related water quality parameters and observed characteristics and effects which can be related to this study will be mentioned. Tables I, and II summarize the researched literature.

Weibel _et al_. (5) performed one of the earlier studies on water quality of urban runoff in 1962-1963. Such work elevated the concern among researchers that urban runoff quality can possibly have a far greater impact on receiving waters than treated wastewater. A small drainage basin consisting of residential and light commercial land uses in Cincinnati, Ohio was the study area. After sampling for a 13 month period, the following mean concentrations were reported: pH value of 7.5, 210 mg/l suspended solids (SS), 53 mg/l volatile suspended solids (VSS), 99 mg/l chemical oxygen demand (COD), 0.6 mg/l ammonia-nitrogen (NH_3-N) and 2.3 mg/l as nitrogen (N) total kjeldahl nitrogen (TKN). The COD mean concentration was near the strength of secondary sewage plant effluent quality. Also, the SS mean concentration was about the strength of raw domestic sewage while the VSS portion of the SS was much lower than for raw sewage. The coliform counts were found to be high and indicated nonhuman sources because fecal

TABLE I.--Urban Land Drainage Characteristics from Various Field Investigations[a]

Investigator & Location	COD (mg/l)	SS (mg/l)	VSS (mg/l)	Total P (mg/l as P)	TKN (mg/l as N)	NH_3 (mg/l as N)
Weibel (Cincinnati, OH)						
Mean	99	210	53		2.3	0.6
Range	20-610	5-1200	1-290			0.1-1.9
Colston (Durham, NC)						
Mean	170	1223	122	0.82	0.96	
Range	20-1042	27-7340	5-970	0.2-16	0.1-11.6	
Pitt (San Jose, CA)						
Mean	200	210	33		6.7	
Range[c]	77-350	41-570	5-40		3.1-15	
Pirner (Rapid City, SD)						
Mean	230	2564	225	0.23		
Range	50-925	62-7518	12-603	0.09-0.40		
Kluesener (Madison, WI)						
Mean		280		0.98	3.95	0.45
Wanielista (Orlando, FL)						
Range[b]	8-285	1-372		1-0.17	0.07-3.87	

TABLE I.--Continued

Investigator & Location	COD (mg/l)	SS (mg/l)	VSS (mg/l)	Total P (mg/l as P)	TKN (mg/l as N)	NH_3 (mg/l as N)
Ellis (Littleton, CO)						
Mean		240	61		1.9	0.44
Range		24-1340	0-268		0.20-9.5	0.03-1.2
Ellis (Lakewood, CO)						
Mean		1170	170		3.0	0.74
Range		72-6600	15-808		0.09-17	0.01-8.1
Ellis (Denver, CO)						
Mean		130	52		3.6	0.70
Range		10-908	8-442		0.21-17	0.00-2.4
Hajas (Butler, PA)						
Range[e]	53-608				1.94-8.3	0.31-4.52
Hajas (Summary[d])						
Mean	205	608		0.5		
DeFilippi (District of Columbia)						
Mean	335	1697	145			
Range	29-1514	130-11280	0-800			

TABLE I.--Continued

Investigator & Location	pH	Specific Conductance (μmhos/cm @ 25°C)	Fecal Coliform (Colonies/100 ml)	Reference
Weibel (Cincinnati, OH)				5
Mean	7.5			
Range	5.3-8.7			
Colston (Durham, NC)				7
Mean			2.3×10^4	
Range			$100 - 2.0 \times 10^5$	
Pitt (San Jose, CA)				8
Mean	6.8	93		
Range[y]	6.3-7.0	33-130	>2400	
Pirner (Rapid City, SD)				9
Mean		365		
Range		140-2400		
Kluesener (Madison, WI)				10
Mean				
Wanielista (Orlando, FL)				11
Range[e]	8.47-7.02	359-77		

TABLE I.--Continued

Investigator & Location	COD (mg/l)	SS (mg/l)	VSS (mg/l)	Total P (mg/l as P)	TKN (mg/l as N)	NH_3 (mg/l as N)
Ellis (Littleton, CO)						
Mean		240	61		1.9	0.44
Range		24-1340	0-268		0.20-9.5	0.03-1.2
Ellis (Lakewood, CO)						
Mean		1170	170		3.0	0.74
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Mean		130	52		3.6	0.70
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Hajas (Butler, PA)						
Range[e]	53-608				1.94-8.3	0.31-4.52
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Mean	205	608		0.5		
DeFilippi (District of Columbia)						
Mean	335	1697	145			
Range	29-1514	130-11280	0-800			

TABLE I.--Continued

Investigator & Location	pH	Specific Conductance (μmhos/cm @ 25°C)	Fecal Coliform (Colonies/100 ml)	Reference
Ellis (Littleton, CO)				12
Mean		140		
Range	6.5-9.0	50-320		
Ellis (Lakewood, CO)				12
Mean		150		
Range	6.5-8.9	75-470		
Ellis (Denver, CO)				12
Mean		180		
Range	6.3-8.5	<50-700		
Hajas (Butler, PA)				15
Range[e]			$4.1 \times 10^4 - 2.7 \times 10^6$	
Hajas (Summary[d])				15
Mean				
DeFilippi (District of Columbia)				14
Mean	6.5		3.1×10^5	
Range	6.0-7.2		$4.0 \times 10^4 - 1.3 \times 10^6$	

a Most sampling took place in a separate storm sewer while others sampled in an open ditch (predominantly unsewered) or a small ravine downstream from one or more separate storm sewer outfalls.

b Second value reflects high flow condition; drainage from commercial area only.

c Flow-weighted.

d Summary of 20 cities, storm sewers, and unsewered areas.

e Range of mean concentrations for listed storm events.

TABLE II.--In-Stream Water Quality During Runoff

Investigator & Location	COD (mg/1)	SS (mg/1)	VSS (mg/1)	Total P (mg/1 as P)	TKN (mg/1 as N)	NH_3 (mg/1 as N)
Wanielista[a] (Orlando, FL)						
Range[f]	26-70	2-35		1.7-1.0	0.06-0.88	
Harms[b] (Waynesboro, VA)						
Range	15-36	38-139		0.07-0.39	0.7-1.7	
McConnell[c] (Woodall Creek near Atlants, GA)						
Mean		570				0.21
Range		60-2400				0.04-0.71
Meadows[d] (Brush Creek near Johnson City, TN)						
Range[g]	30-67					
Harms[e] (Rapid City, SD)						
Range[h]	22-42	17-522	3-35			0.01-0.02

TABLE II.--Continued

Investigator & Location	pH	Specific Conductance (μmhos/cm @ 25°C)	Fecal Coliform (Colonies/100 ml)	Reference
Wanielista[a] (Orlando, FL)				11
Range[f]	7.62-6.73	270-153		
Harms[b] (Waynesboro, VA)				16
		64-230		
McConnell[c] (Woodall Creek near Atlanta, GA)				17
Mean			7.0×10^4	
Range			$1.0 \times 10^4 - 3.4 \times 10^5$	
Meadows[d] (Brush Creek near Johnson City, TN)				18
Range[g]				
Harms[e] (Rapid City, SD)				19
Range[h]	8.22-7.50	364-405	370-3700	

[a] Watershed area 17% urban and two point sources (WWTP).
[b] Drainage areas at sites ranged 0.5 to 6% urban.
[c] Drainage area at site 92% urban.
[d] Watershed area 47% urban.
[e] Drainage areas between extreme sites predominately urban.
[f] Second value of range reflects high flow condition.
[g] One storm event, range over six sampling sites.
[h] First value reflects mean of values determined at site on stream just upstream from urban area - second value reflects mean of values determined at site on stream nearly downstream of urban area.

streptococcus counts exceeded the fecal coliform counts. Such counts would be of some concern for water activities where direct contact was involved.

Bryan (6) and Colston (7) characterized urban runoff quality on the upper third Fork Creek basin in Durham, North Carolina. Bryan (6) performed the first study on the basin during the period of 1969 to 1970 and concluded that the total organic matter as measured by the COD test and the total solids loading contributed by the urban stormwater were greater than that attributable to the average strength of the raw municipal wastewater generated in the study area. The total phosphorus loading from the urban runoff was not significant when compared with the phosphorus content in raw municipal wastewater.

Colston (7) in 1971-1973 (36 storm events) found the mean concentrations shown in Table I. Urban land runoff was determined to be a significant source of pollution when compared to raw municipal waste generated within the study area. On an annual basis, the urban runoff yield of COD was equal to 91 percent of the raw sewage yielded for the same area, and the urban runoff SS yield was 20 times that contained in raw municipal wastes. Colston (7) judged that about 20 percent of the time downstream water quality was primarily governed by urban land runoff. He also found that concentrations of heavy metals were two to fifty times greater in urban land runoff than typical raw waste.

The urban land use variations within the Durham study area were not found to influence the quality of urban land runoff. Also, the elapsed time from the last storm was not found to be a significant parameter to quantify. Pollutant concentrations tended to increase with an increase in rate of runoff and decrease as the time from storm start increased. This Colston (7) indicated as a first flush effect.

Water quality data of urban runoff were obtained from a street cleaning demonstration study in 1977 in San Jose, California by Pitt (8). These data were analyzed to estimate the specific chemical compounds, to estimate those that would remain soluble, and those that would settle out into the receiving water sediments. Flow weighted parameter concentrations for the Keyes and Tropicana study areas are shown in Table I.

A watershed in Rapid City, South Dakota, was studied to determine the characteristics of urban runoff as a source of pollution. Pirner and Harms (9) found that urban runoff contributed gross quantities of sediment to a receiving body of water (Rapid Creek) and that treatment should focus primarily on solids removal. However, it was cautioned that a large portion of the sediment contained in the runoff would not be removed by simple settling. During the duration of the study from May, 1975 to September, 1975, a total of fifteen runoff events were sampled of which eight were sampled completely throughout the hydrograph. The mean values of several constituents are listed in Table I.

A comparison was made of SS loading from urban runoff to an existing point source downstream from the studied Meade Street drainage basin. They found that a major storm event can contribute as much sediment to Rapid Creek as six months of the continuous point source discharges.

Kluesener and Lee (10) sampled stormwater from a separate storm sewer in Madison, Wisconsin. This study primarily focused on the quantity of nutrients in the stormwater and determined the mean concentrations presented in Table I. One of the objectives for the nutrient investigation was to determine the significance of urban runoff relative to other known sources of nutrients influent to a small lake in Madison. When the runoff data from the separate storm sewer draining stormwater from the Manitou Way basin was extrapolated to the entire Lake Wingia basin, it was determined that approximately 80 percent of the total phosphorus and about 35 to 40 percent of the total nitrogen influent to Lake Wingia arises from urban runoff. Another finding by Kluesener and Lee's (10) 1970 investigation was that nutrient and suspended solids concentrations decreased with time. This phenomenon was later supported by other investigators (7,9,12,15).

An urban area in downtown Orlando, Florida was investigated during storm events for runoff water quality by Wanielista et al. (11). Two locations were selected to represent drainage from commercial and residential sections of the Lake Eola drainage basin. Data from the commercial drainage for the wet period of May and June, 1975, are given in Table I. The water quality data were found to show a general decrease in pH and specific conductance values during the rainy season when compared to the dry season, while parameters such as SS, COD, and nitrogen concentrations will generally increase.

Urban runoff data were collected from 1975 to 1977 on three separate drainage basins in the metropolitan area of Denver, Colorado. Ellis et al. (12) found the constituent concentrations in the runoff varied considerably among the three basins. They also determined that the antecedent precipitation, or the number of days since the last street sweeping, had no apparent effect on runoff quality. This was contrary to the findings by Defilippi and Shih (14), Pitt (8) and Sartor (13).

A drainage basin in Littleton, Colorado (Littleton site), consists of 75 percent in single family dwellings and 25 percent in parks and open space. Street gutters and open ditches are the main drainage types for flow conveyance. Lakewood basin had approximately 50 percent in undeveloped land, 30 percent in multifamily dwellings, and 20 percent in commercial development. Street gutters convey storm runoff to a storm sewer crossing the basin.

The Denver basin had approximately 37 percent in multifamily dwellings, 37 percent in mixed single family and multifamily dwellings, 20 percent in commercial development, and 6 percent in parks. The basin is underlain by a complex storm sewer system that conveys the runoff to an outfall at the South Plate River. The mean concentrations for the three basins are shown in Table I (12). Overall, the Denver site's storm runoff tended to have the largest parameter concentrations, whereas storm runoff from the Littleton site had the smallest parameter concentrations. Some snowmelt runoff work was completed at the sites. It was determined that the constituent concentrations generally peaked during the middle of day, corresponding with periods of maximum melting and runoff.

An investigation was conducted in the District of Columbia to compare the water quality of urban runoff collected in separate storm sewers and combined storm sewers. DeFelippi and Shih (14) monitored nine storms in 1969 at a separate storm sewer. They concluded to reconsider the approach of total separation of existing combined sewer systems because significant pollution loads were found in separate storm sewers. Data are listed in Table I.

Another separate storm sewer study on urban stormwater quality was made in Butler, Pennsylvania by Hajas et al. (15). Table I gives ranges of parameter values for three storm events. A high standard deviation of the water quality parameters was noted. The researchers felt this was caused by the pollutant concentrations in urban stormwater varying with time.

A summary of national stormwater pollutant concentrations was recently published by Hajas et al. (15). The mean concentrations of separate drainage areas for 20 cities for some constituents are listed in Table I. Obviously there are many differences which are due in part to factors such as variations in topography, soils, land use variables, climate, and rainfall intensity.

Literature Summary of In-stream Water Quality

A limited number of studies have assessed the water quality in small streams resulting from stormwater runoff. Two locations were selected for sampling and water quality analysis during storm runoff events on Shingle Creek near Orlando, Florida. The Shingle Creek drainage basin is 74 percent non-urban, 17 percent urban and 9 percent surface water. Wanielista et al. (11) determined values reflecting the high flow conditions for the furthest downstream location as listed in Table II. The pH and specific conductance values generally decreased as the flow in the stream increased. However, increases in COD and nitrogen concentrations were observed when the stream flow increased. These trends are similar to urban land runoff. Wanielista et al. (11) also pointed out that concentrations for certain constituents from nonpoint sources may decrease during rainfall events. However, the total mass of pollutants was most likely to increase. Therefore, the researchers proposed that mass loading standards should be initiated, in addition to concentration, to define the extent of pollutant effects in receiving waters.

The primary purpose of the nonpoint source pollution study near Waynesboro, Virginia was to investigate the Water quality effects from agricultural, forest land and urban runoff on receiving waters and compare the nonpoint sources to contributing point sources. The Upper South River basin was chosen because it receives agricultural, forest land and urban runoff as well as significant point sources. Harms and Southerland (16) determined that urban runoff contributed substantial pollutant loads during storm runoff events. The range of mean concentrations for the four sites on South River are given in Table II. Even though point sources contributed only negligible quantities of sediment but the majority of the nutrients to receiving waters during dry periods, these point source nutrient contributions were over-shadowed by the total nonpoint source contributions during major storm events. Also during major storm events, nonpoint sources contributed about 98% of the sediment of which urban runoff was the largest contributer. The organic pollution resulting from nonpoint runoff was insignificant.

McConnel (17) conducted an extensive study on streams tributary to the Chattahoochee River near Atlanta, Georgia. Generally, he found the streams to degrade in water quality during periods of stormwater runoff. Woodall Creek is heavily impacted by the 92% urban basin with no known point sources or combined sewer overflows during storm runoff (See Table II).

Brush Creek, located in Washington County, Tennessee, was studied to assess nonpoint source pollution in small streams during a wet period. The Brush Creek watershed is comprised of approximately 33 percent in residential land use, 14 percent in commerce, industry or streets, 39 percent in agriculture, and 14 percent in woodland. During the one storm event sampled, the range of COD concentrations for three of six sites on the stream was 30-67 mg/l. Meadows _et al._ (18) found Brush Creek to be relatively free of organics and other oxygen demanding pollution during dry weather periods.

A short term sampling program was conducted in June and July, 1977, to determine how urban runoff affected water quality on Rapid Creek which flows through Rapid City, South Dakota. This work documented the urban stormwater problem in Rapid City and proposed water quality management planning for the local government's 208 plan. Harms (19) found the water quality in Rapid Creek during low flow or dry weather conditions (through Rapid City's reach) meeting the stream's water quality standards. However, many of the standards were being violated during periods of storm runoff. Sampling Site 1, just upstream from Rapid City proper, was considered the control (non-urban) point of the study. From Site 1 to Site 4, Rapid City's urban storm runoff impacted the stream. Mean concentrations for three storm events for Site 1 and Site 4 respectively are shown in Table II. The ranges show the degradation of the stream as it flows through town during a runoff event. Evidence also seemed to indicate that the water quality of Rapid Creek degraded from site to site during dry weather flows.

The City of Dallas, Texas undertook a study of an actual storm event to identify and quantify the effects on Trinity River of pollutants washed into it by stormwater runoff. During the two-day storm in February 1977, the nonpoint sources contributed 99 percent of the suspended solids loading. When comparing the nonpoint contribution to the average 1976 dry weather loading of 57.1 tons/day of SS at South Loop 12 on the Trinity River, the nonpoint load was 3,464 percent of the mean daily dry weather loading. Also, this storm event loading can be compared to the number of days of treated sewage effluent (135 MGD) that would be required to produce an equivalent SS loading. It was determined that 361 days would be required. Other impacts measured were the large quantities of nutrients, high coliform levels and significant metals and pesticides (20).

The impact of nonpoint source pollution, mainly urban runoff, upon receiving streams must be assessed if effective water quality management strategies are devised. Substantial information has been gathered over the last twenty years to define and characterize urban land runoff by identification of various land use activities. The current assessment practice is to monitor in-stream water quality throughout the urban reach of the stream and correlate such data to land use and human activities. When such assessments becomes conclusive, then opportunities for controlling urban runoff problems will become more evident.

Antecedent Dry Days

There are other factors to be considered when looking at the quality of urban runoff. One of them is the source of urban runoff itself, precipitation. The following discussion will look at the period of time since the last rain and relate it to urban runoff quality. This is referred to as antecedent dry days.

In a 1974 article Whipple, Hunter, and Yu (21) assumed that the pollution in urban runoff varied with the time since the last rain. That is to say that a longer dry period caused more pollution. Bradford (22) made this same assumption in his article. This assumption was proven only to some extent by Sartor *et al*. (13). They found that the amount of solids that accumulated on streets depended on the length of time since the last rain or flushing.

However, other studies could not support this assumption. Whippel *et al*. (23) found no relationship between pollutant loading and antecedent dry days. Likewise, the Denver study (12) revealed that antecedent dry days did not affect runoff quality. Whipple, Hunter, and Yu (24) wrote another article in 1977 that dealt solely with correlations between runoff pollution and antecedent dry days. They sampled an urban watershed in New Jersey and tested for suspended solids, total phosphorus, BOD, and three different metals. A relationship was not found between runoff pollution and the number of days since the last rainfall. In a Texas study (25), researchers correlated suspended solids loading and antecedent days without rainfall. For two urban watersheds they squared the correlation coefficient (r). The resulting r^2 values were 0.25 and 0.00. This indicated to the authors that a significant relationship was not present between urban runoff pollution and the number of dry days previous to the storm.

II. THE STUDY AREA

General

The study area lies within the physical boundaries of Rapid City, South Dakota. Figure 1, a vicinity map which also indicates the locations of the six sampling stations, is shown on the following page. A larger, more detailed representation (Plate 1) can be found attached to the rear cover of Appendix A. Rapid City is located at the foothills to the Black Hills in western South Dakota and is the county seat for Pennington County. Rapid City is the largest community in western South Dakota and is the business center for much of the surrounding area.

Between 1940 and 1960, Rapid City experienced a dramatic growth rate resulting in a 1960 population of 42,399, up from 13,844 in 1940. A more stable, much slower growth occurred in the next two decades, giving a 1980 census figure of 46,492.

Land Use

A summary of the land use information is presented in Tables III and IV. The land uses were split into 5 categories; non-urban, residential (urban and rural), commercial and industrial, institutional and other. A description of each category is given on Table III. The split between urban and rural residential was made at two dwellings per acre. In other words, rural residential areas have two or less dwellings per acre. A pictorial presentation of the land use information is shown on a large fold-out map which can be found attached to the cover of this report.

An examination of the information in Tables III and IV shows that the non-urban land use category is a substantial percentage of the total land area for each sampling station, even Sta. No. 2 through 6 which are considered urban sampling locations. These are relatively large watersheds and the percentage of land use in all probability does not reflect the percentage of runoff contributed to Rapid Creek. For example, at Sta. No. 3, the non-urban use category is 59.1 percent. Yet except for major events, it was felt that the majority of the runoff originated over the 40.9 percent of the area which reflected urban activities (quarry area included). It was beyond the scope of the current project to evaluate the contributing areas for various types of hydrologic events.

Sampling Locations

The six sampling stations are indicated on Figure 1. Ideally, a sampling station should have been located just upstream of all urban development, and just downstream from the city. Station 1 essentially satisfies the upstream station, but some urban influence will manifest

TABLE III. -- Percentage of Land Use* Between Sampling Stations

	Non-urban	Residential		Commercial & Industrial	Institutional	Other
		Urban	Rural			
Station 1	95.9	0.0	4.0	0.1	0.0	0.0
Station 2	77.8	7.6	8.9	0.4	1.9	3.3
Station 3	59.1	2.2	0.4	18.0	1.6	18.6
Station 4	32.1	31.2	4.4	13.6	4.4	14.4
Station 5	18.8	18.8	1.4	25.8	10.1	25.1
Station 6	34.3	46.5	0.7	6.4	5.1	7.0

*Land use, by category:

(1) Non-urban includes forestland, grassland, agricultural land and water.

(2) Urban residential refers to common city dwellings, paved streets, etc. Rural residential refers to dwellings on larger lots, acreages, many unpaved streets or drives, etc.

(3) Commercial and industrial includes stores, offices, and plants.

(4) Institutional includes schools, hospitals, and retirement homes.

(5) Other includes parks, undeveloped areas, and quarries above Sta. 2 (0.2% of basin area) and Sta. 3 (12.5% of basin area).

TABLE IV. -- Area, in Acres, of Land Use* Between Sampling Stations

	Non-urban	Residential Urban	Residential Rural	Commercial & Industrial	Institutional	Other	Total
Station 1	32,350		1,350	25	5	0	33,730
Station 2 West Rapid City	16,349	1,581	1,866	92	410	692	20,990
Station 3 Deadwood Ave	2,288	85	15	699	62	723	3,872
Station 4 Central Business District	1,171	1,137	160	498	159	525	3,650
Station 5 East Rapid City	303	303	23	415	162	404	1,610
Station 6 Robbinsdale	696	944	14	131	103	142	2,030

*See TABLE III for land use explanation.

itself at Sta. 1 because of an increase in density of dwellings and the highway traffic just upstream. The benefits of many years of hydrologic data available at this station from USGS records overshadowed any negative effects. It was not hydraulically possible to establish a sampling station downstream from the study area before other non-point sources of runoff would enter Rapid Creek. Consequently, a theoretical station, No. 56, was developed which mathematically establishes downstream values based on mixing the loads present at Sta. 5 (the last station on Rapid Creek) and Sta. 6 (the last major urban drainage into Rapid Creek).

A description of each sampling station along with the justification for selection follows:

Station No.	Description	Rationale
1	Located at the USGS gaging station on Rapid Creek at the west edge of Rapid City.	A background water quality station on the creek before significant urbanization occurs. Data from samples at this station will represent baseline conditions during a storm event. Comparing the data from this location with the rest of the data assists in determing the actual effects of the urban area.
2	Located on Rapid Creek at foot bridge in Sioux Park.	A station in the western part of town below some major urban discharges. Located below Lime Creek, but above the municipal water treatment plant.
3	Located on Creek at USGS gage near Black Hills Packing Co.	A station near the center of Rapid City. All the drainage from western Rapid City plus any drainage from the Cement Plant and quarries enter the creek prior to this station.
4	Located on Rapid Creek at the E. Main bridge.	A sampling station just before the fairgrounds. The stream has begun to flatten out here, meanders are more frequent, and urban drainage from both the downtown area and North Rapid City are included in the stream flow.

Station No.	Description	Rationale
5	Located on Rapid Creek at the St. Patrick Street bridge, just above the Meade St. drainage channel.	This sampling station will be used to help determine the stream water quality as Rapid Creek exits the community. Sampling and mixing considerations make it more feasible to determine the quality below Rapid City theoretically by sampling above and on the Meade St. drainage.
6	Located on the Meade St. drainage channel.	A station on the major urban drainage way to Rapid Creek. Some background water quality data are available for this drainage. The Meade St. drainage channel drains over 20 percent of the Rapid City land area. Data collected from this location should yield the general range of pollutants that enter Rapid Creek from urban runoff. Data from Sta. 5 will be used with data from this station to determine the stream water quality at the city limits. There is only minimal surface drainage between these two sites.

Climate and Hydrology

The Black Hills area and Rapid City have a climate of their own. Since these areas are situated in the heart of the North American Continent, they are near the paths of many low and high pressure systems and have the extremes of summer heat and winter cold that are characteristic of continental climates. The Black Hills, many of which are more than 5,000 feet above sea level, with some peaks above 7,000 feet, exert a pronounced influence on the climate of Rapid City and other Black Hills communities.

Warm, chinook winds and frequent sunny skies make the Black Hills area the warmest part of South Dakota in the winter. Also, because of the tendency for very cold air masses to stay at low elevations, some of the artic air outbreaks do not reach Rapid City and pass east of Rapid City. The mean temperature for the winter months of December, January and February is 24.6°F (26). Generally, one or two blizzards may occur each winter.

Summer days are normally warm with cool, comfortable nights. The mean temperature for the summer months of June, July and August is near

69°F with July's monthly mean (72.3°F) temperature being the highest (26). Rainstorms occur most frequently in early summer and thunderstorms are most frequent the rest of the summer months.

Autumn and spring seasons are transition periods for weather extremes. Wide variations usually occur in temperatures and snow may fall as early as the first week in October or as late as mid May.

The annual precipitation total for Rapid City is near 18 inches which is typical of a semiarid region. The growing season ranges at about 150 days near Rapid City with the greatest amounts of precipitation occurring during the growing season. The heaviest snowfall amounts are expected in early spring (26). The number of occurrences per year of measurable rainfall from March through November is shown in Figure 2.

Extreme variations in flow have been recorded in Rapid Creek. For the water year 1980 (October 1979-September 1980), normal flows ranged from 15 to 85 cubic feet per second (cfs). The major reason for the flow variance is due to flow regulation from Pactola Reservoir. During runoff events for the same water year, flows as high as 645 cfs have occurred and flows as high as 1,000 cfs can be expected somewhere in the urban reach of the stream, likely near the exit of the urban drainage area. A mostly urban drainage basin, the Meade Street Drainage Basin, had flows as high as 380 cfs on June 15, 1980 (27). Flows near 1200 cfs have been known to exist in the basin (28).

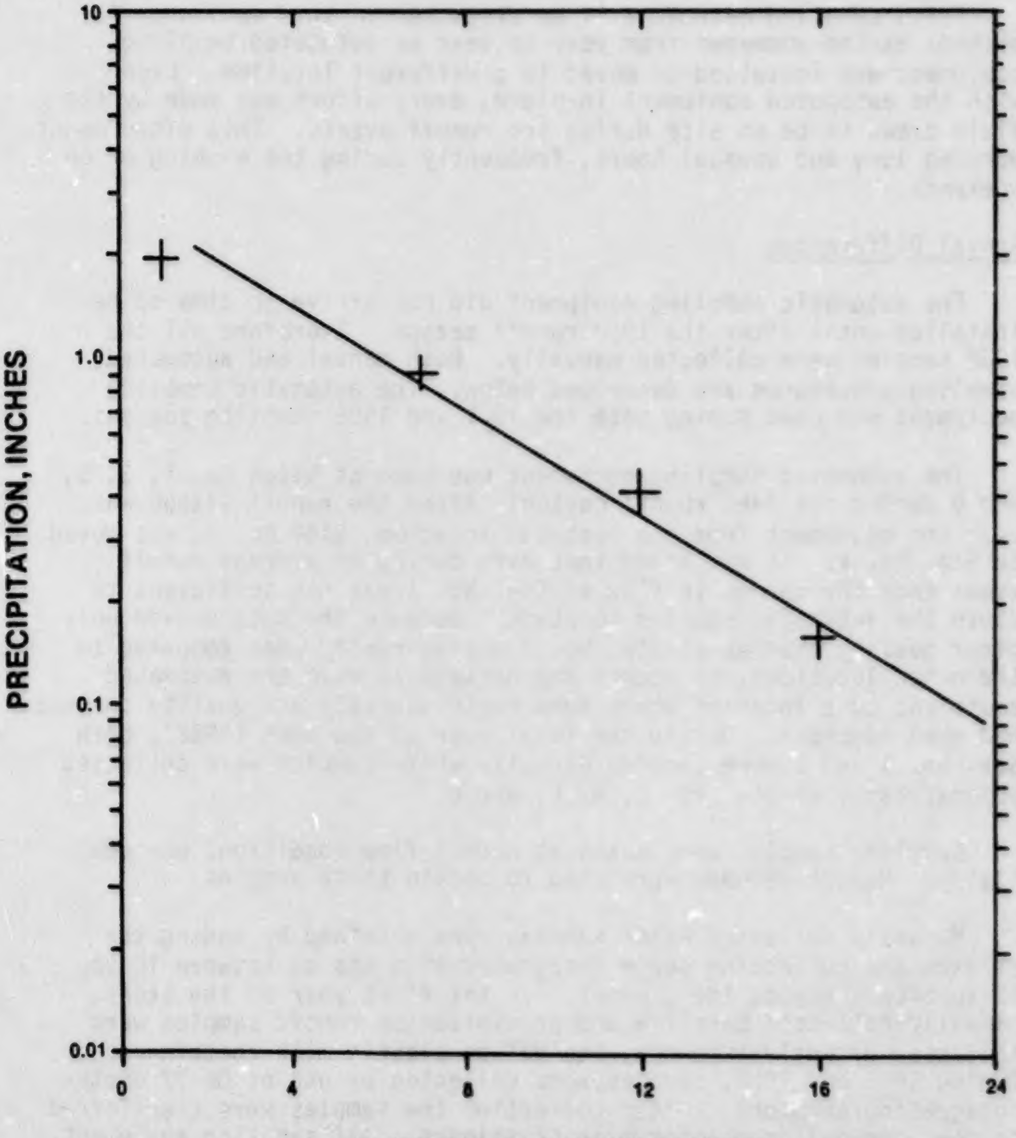

Figure 2. Number of Occurrences of Measurable Rainfall During the period of March through November Per Year.

III. FIELD TECHNICS

General

Field sampling methods will be discussed in this section. The methods varied somewhat from year to year as automated sampling equipment was installed or moved to a different location. Even with the automated equipment in-place, every effort was made by the field crews to be on site during the runoff events. This often meant working long and unusual hours, frequently during the evening or on weekends.

Annual Differences

The automatic sampling equipment did not arrive in time to be installed until after the 1980 runoff season. Therefore all the 1980 samples were collected manually. Both manual and automated sampling procedures are described below. The automatic sampling equipment was used during both the 1981 and 1982 sampling seasons.

The automated sampling equipment was used at Sites No. 1, 3, 5, and 6 during the 1981 runoff season. After the runoff season was over the equipment from the upstream location, Site No. 1, was moved to Sta. No. 4. It was found that even during an average runoff event that the change in flow at Sta. No. 1 was not sufficient to cause the automatic sampler to start. Because the data showed only minor quality changes at Sta. No. 1 during runoff when compared to the other locations, it seemed appropriate to move the automated equipment to a location where more rapid quantity and quality changes had been recorded. During the final year of the work (1982), both Sta. No. 1 and 2 were sampled manually while samples were collected automatically at Sta. no. 3, 4, 5, and 6.

Baseline samples were taken at normal flow conditions periodically. Manual methods were used to obtain these samples.

Manually collected water samples were obtained by wading the streams and collecting depth integrated aliquots at between 10 to 15 verticals across the channel. In the first year of the study, manually collected baseline and precipitation runoff samples were collected directly into new, one-gallon plastic milk containers. During 1981 and 1982, samples were collected by use of DH-77 depth-integrating samplers. After collection the samples were transferred to new, one-gallon plastic milk containers. All sampling equipment and containers were rinsed three times with native water prior to taking the first aliquot. The sample was immediately cooled to 4°C. Date, time, and stage were recorded immediately before and after sample collection.

The automated sampling equipment, referred to as an urban hydrology monitoring system by USGS, incorporates a microprocessor based system control unit to receive a record on site and to control the automated water sampling device. The system would switch on to storm mode when a select stage, corresponding to a definite discharge, was reached in-stream during a storm event. The system would make continuous recording data (time, date, stage, accumulated rainfall, and sequential sample number) at a pre-determined time interval ranging from 30 seconds to 1 hours. If a rapid rise in stage occurred, the timing sequence was over ridden and additional samples were collected. Samples were pumped into new, one-gallon plastic containers which were stored in a refrigerator unit, at 4°C, and later, as soon as possible, transported to the South Dakota School of Mines and Technology (SDSM&T) environmental engineering laboratory. Under most conditions, samples were delivered to the lab within three hours of collection. A sketch of this equipment is shown in Figure 3.

Data for events No. 27 and 30 were used in an attempt to determine if the automatic samplers were collecting representative samples. Manual samples were collected at the same time that the automatic sampler was going through its sampling sequence by integrating with depth at various vertical sections along the horizontal cross-section of the sampling station. All manual samples were collected using standard USGS equipment and procedures for collecting water quality samples.

Suspended solids (SS), and volatile suspended solids (VSS) tests were conducted in duplicate on all individual samples for both events. Chemical oxygen demand (COD) was also done on the first sample set. Results of these tests are included with the other data in Appendix A.

Tables V through X analyze the variations in sampling methods. It has been suggested that the data are skewed and should be evaluated in the log-normal phase. The skewness coefficient was determined for the data for samples from the automatic samplers in both normal and log-normal modes. Values for skewness are given in Table V. The skewness coefficient will take on a value of zero when the data are completely symmetrically distributed. Thus is appears that all the data are better evaluated in the log-normal mode. A positive skewness value indicates the data are clustered to the left with the higher readings being the extreme values to the right of the distribution.

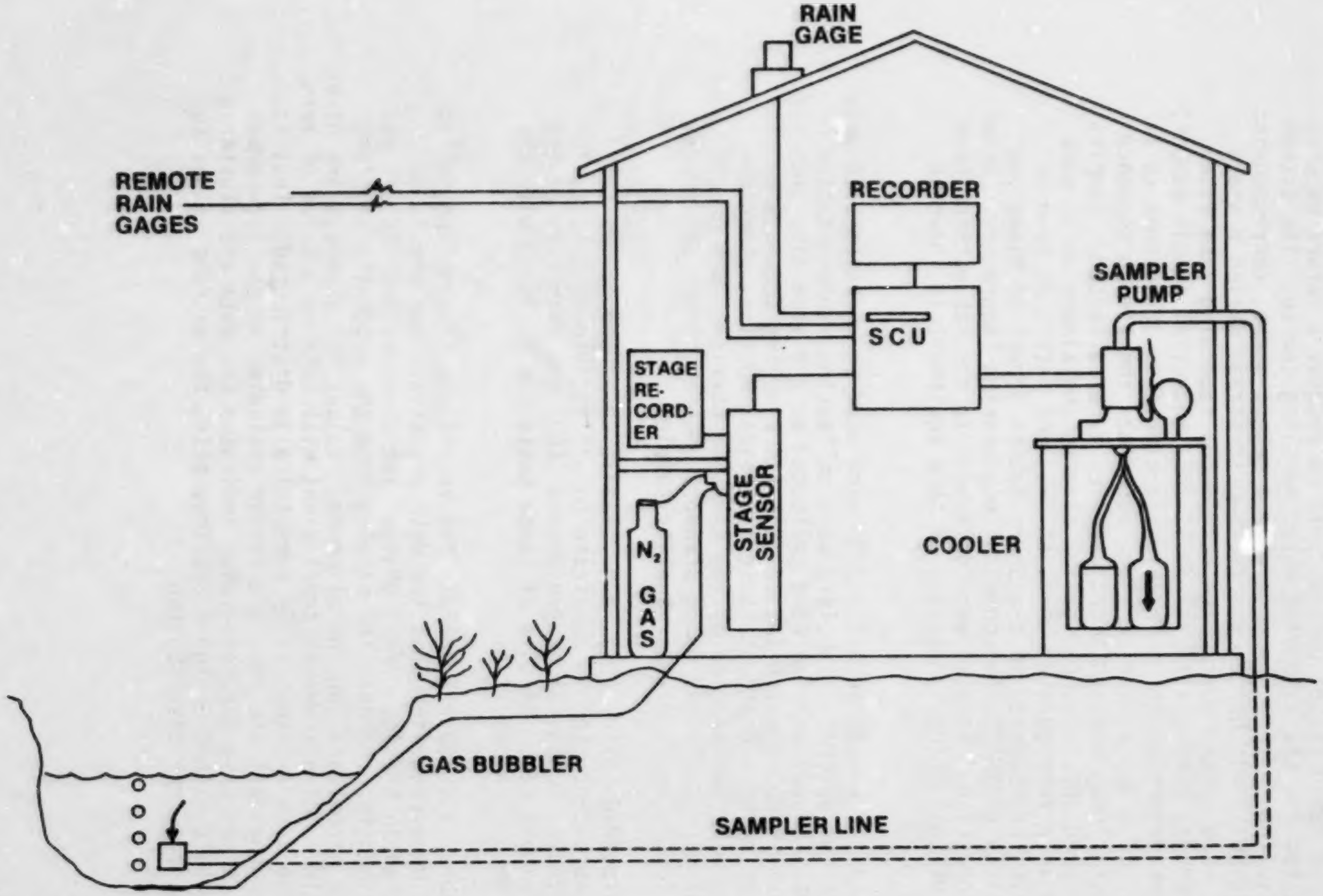
RAIN GAGE
REMOTE RAIN GAGES
RECORDER
SAMPLER PUMP
S C U
STAGE RE- CORD- ER
STAGE SENSOR
N_2 GAS
COOLER
GAS BUBBLER
SAMPLER LINE

Figure 3. -- Automated sampling station

TABLE V. -- Evaluation of Skewness

Site No.	n	Skewness Coefficient Normal Distribution		Skewness Coefficient Log-Normal Distribution	
		SS	VSS	SS	VSS
3	9	1.42	1.30	0.48	0.52
4	7	0.92	0.87	0.15	0.16
5	7	0.31	0.30	0.23	0.24
6	6	1.08	0.94	0.19	0.01

*n=number of paired samples.

A comparison of the automated versus manually depth-integrated samples was made using paired "t" statistics (29). Comparisons were made in both the conventional, normally distributed mode, and also in the log-normal mode. Results are given in Table VI. Perhaps the single most limiting factor for this approach is the sample size, which varied from 6 to 9. A sample size of about 30 sets would be desirable. It is not realistic to attempt to obtain this many samples. In generating the data shown in Table VI, two sampling events were sacrificed for the normal compositing, 58 samples were collected, and 116 SS and VSS tests were conducted.

TABLE VI. -- Paired Student's t Test Results

Site No.	n	t.05	t, Normal-Distr.		t, Log-Normal Distr.	
			SS	VSS	SS	VSS
3	9	2.31	-1.34	0.00	-2.80*	0.01
4	7	2.45	2.54*	4.25**	2.81*	3.36*
5	7	2.45	0.00	1.22	0.68	1.32
6	6	2.57	-0.75	1.00	-0.27	1.39

*A significant difference exists between automated and depth-integrated samples.

**A highly significant difference exists between automated and depth-integrated samples.

The data of Table VI seem to indicate that the sampler at Site No. 4 does not give representative samples based on a 95% confidence level. This statement appears to be true based on both the SS and VSS test. The SS test was the test of choice for comparison purposes. However, it was speculated that the sand in the bed-load may distort the values in the depth-integrated samples and that the VSS test may be more representative. This indeed may be the case for Site 3 as it is the furthermost upstream station where more sand is evident.

When evaluating these data, we must remain aware of the previous discussion regarding sample size. For example, if the paired "t"-test was performed on the SS data of Site 4 by eliminating one sample in turn, the resulting 7 tests would not show a significant difference 5 times (an acceptance level of 71%).

Perhaps a more practical approach would be to evaluate the data based on the difference and the percentage of difference between the two methods of sample collection. This scheme is presented in Tables VII to X. Site 3 does seem to show the effects of a heavier bed-load as most of the depth-integrated samples had higher suspended solids. Even then, the average difference in concentration is slightly less than 10%.

TABLE VII. -- Differences in Paired Samples for Site No. 3

Sample	SS, mg/L		VSS, mg/L	
	Δ*	%Δ	Δ	%Δ
27-3.1	- 10	-12.05	0	0
27-3.2	- 16	-13.91	0	0
27-3.3	- 3	- 2.68	-3	-23.08
27-3.4	- 8	- 7.34	2	12.50
27-3.5	- 16	-12.70	0	0
30-3.1	- 74	-15.70	-1	- 1.92
30-3.2	-170	-13.82	-4	- 3.92
30-3.3	43	7.06	4	7.69
30-3.4	7	1.67	2	5.26
	$|\overline{\%\Delta}|$	= 9.66%	$|\overline{\%\Delta}|$	= 6.04%

*Δ = Automated Sample Value - Depth Integrated Sample Value.

%Δ = 100 Δ/Automated Sample Value.

$|\overline{\%\Delta}|$ = Mean of absolute values of %Δ.

TABLE VIII. -- Differences in Paired Samples for Site No. 4

Sample	SS, mg/L		VSS, mg/L	
	Δ*	%Δ*	Δ	%Δ
27-4.1	4	1.67	0	0
27-4.2	45	17.24	3	10.71
27-4.3	13	6.25	2	8.33
30-4.1	30	2.04	3	2.29
30-4.2	114	14.13	5	6.58
30-4.3	31	5.60	2	3.33
30-4.4	13	1.70	2	2.94
	$|\overline{\%\Delta}|$ = 6.95%		$|\overline{\%\Delta}|$ = 4.88%	

*(see TABLE VII)

TABLE IX. -- Differences in Paired Samples for Site No. 5

Sample	SS, mg/L		VSS, mg/L	
	Δ*	%Δ*	Δ	%Δ
27-5.1	73	20.86	2	6.67
27-5.2	2	0.70	-1	-2.94
27-5.3	15	5.21	7	17.50
27-5.4	-10	-4.17	0	0
30-5.1	-120	-10.91	-4	-4.00
30-5.2	20	1.72	3	2.75
30-5.3	20	2.02	5	5.15
	$|\overline{\%\Delta}|$ = 6.51%		$|\overline{\%\Delta}|$ = 5.57%	

*(see TABLE VII)

TABLE X. -- Differences in Paired Samples for Site No. 6

Sample	SS, mg/L		VSS, mg/L	
	Δ*	%Δ*	Δ	%Δ
27-6.1	-225	-10.74	6	3.61
27-6.2	- 70	- 4.19	-8	-5.88
27-6.3	31	3.63	4	5.88
30-6.1	- 40	- 0.86	-10	-2.56
30-6.2	0	0	22	9.24
30-6.3	100	7.14	18	13.24
	|$\overline{\%\Delta}$|	= 4.43%	|$\overline{\%\Delta}$|	= 6.74%

*(see TABLE VII)

The data in Table VIII show that the automated samples consistently have higher SS than the depth-integrated samples. The difference does not appear to be alarming as the average difference is about 7 percent.

It is difficult to make a comparison to evaluate the automatic samples because a firm and true value for each sample is not available. Although unknown, there is undoubtedly some sort of sampling error associated with the depth-integrated method which is being used as the standard in this comparison. In addition, each laboratory test has its own errors and does not yield a single true value.

In conclusion, it appears that the automatic samplers are collecting reasonably representative samples at all the locations. To collect enough samples to confirm this statistically is beyond the scope of the current work. The samples collected at Site No. 4 would appear to be the most suspect, but the average difference between automated and depth-integrated samples is only approximately 7 percent.

Field Parameters

Instantaneous values for flow, dissolved oxygen, conductivity, pH, and temperature were obtained at each station throughout the 3 year study. No attempt was made to correlate this information with the laboratory data gathered from the composite samples. These data are presented separately in Appendix A.

Two sampling stations to obtain information on the atmospheric deposition were maintained throughout the study. One station was located in West Rapid adjacent to Site No. 2. The other atmospheric sampling station was located in Lombardy Industrial Park near where the

Meade Street drainage emptied into Rapid Creek. Samples were collected using an Aerochem Metrics Model 301 sampler which is designed to collect both wetfall (precipitation) and dryfall samples. The atmospheric deposition data are presented and statistically summarized in Appendix A.

Priority Pollutants

Samples for priority pollutant analysis were collected three times during the project (events No. 7, 22, and 28). All samples were obtained manually so the sampling train did not contaminate the samples. Samples were collected at Sta. No. 1, 3, 5 and 6 only. All samples were collected in especially prepared containers (See laboratory techniques). Samples for volatile organics were grab samples collected bubble-free in vials that were capped in the field. The remaining tests were conducted on composite samples. Compositing was done as soon as possible and the samples were iced and shipped by air to an approved laboratory for analysis.

IV. LABORATORY TECHNICS

General

Because of the proximity of the laboratory to the field sampling stations, all sample preparation and preservation was done in the laboratory. Field filtration or sample preservation beyond cooling was not practiced.

As soon as the samples were received in the laboratory, each individual sample was recorded in a sample log manual and then stored at 4°C until composited. The information recorded included the sample identification number, date and time of sampling, sampling location, and the date and time of receipt of the sample at the laboratory.

Compositing

All baseline samples were taken at times when runoff was not occurring so the single sample was representative of the quality and compositing was not necessary. On a few occasions during a short-term runoff event, single samples were used as representing the entire runoff event at the upstream stations. All of these occasions were during the first year of the project and prior to the installation of the automatic sampling equipment. A list of these single sample events is given in Table XI. An appreciable rise in the streamflow and changes in water quality usually were not observed at these stations for these events.

TABLE XI. -- Stations and Events in which Single Discrete Samples were Used as Composites.

Event No.	Sta. No.	Runoff Volume, ac-ft
1	1	1.86
2	1	Negligible
	2	1.86
	3	2.31
	4	5.91
4	1	0.66
	2	8.68
	3	14.0
	4	22.9
5	1	2.48
6	1	0.74

All remaining samples from each station were normally composited into a single sample for each station for each event. Composites were flow weighted composites as explained below. Intentional exceptions were samples from events No. 10, 19, 24, 25, 27, and 30. Analytical deteminations were conducted throughout the hydrograph on discrete samples in order to obtain that additional information for rainfall runoff events No. 10 and 19, and snowmelt runoff events No. 24 and 25. Events No. 27 and 30 were sacrificed to evaluate the automatic samplers as previously discussed.

Flow weighted composites were made for each station using the appropriate aliquot from each discrete sample. Volumes for each aliquot were determined by calculating the volume under the hydrograph that each sample represented, baseflow included. A computer program was developed to compute the correct aliquots. This program is explained in detail in Appendix B of this report.

Composites were produced using a USGS cone splitter (30). The splitter was developed by Bob Middelburg of USGS and splits any sample into 10 equal aliquots. By using the splitter twice (once on 100 percent of the sample, and once on 10 percent of the sample), the aliquot from each discrete sample could be obtained to the nearest one percent. The cone splitter was evaluated for accuracy prior to use. After some practice the error averaged about 3 percent which was the sum of the cone splitter and analytical error. After the composite was properly constituted, the cone splitter was used to split the composite sample into individual containers for storage and/or preservation as shown in Figure 4.

Analytical Methods

Only approved EPA methods were used throughout this investigation. The individual method for each parameter is listed in Table XII.

TABLE XII. -- Analytical Procedures

Parameter	Method	Reference**
Alkalinity	Titration to pH 4.5	Std. methods, p. 278
BOD (5-day)	Electrode method	Std. methods, p. 543
BOD (ultimate)	Electrode method	None
Calcium	Digestion followed by Atomic Absorption	1979 EPA methods, p. 215.1
COD	Dichromate Reflux	Std. methods, p. 550
Chloride	Mercuric nitrate	Std. methods, p. 304

TABLE XII. -- Continued

Parameter	Method	Reference**
*Dissolved ammonia nitrogen	Filtration followed by electrode method	1979 EPA methods, p. 350.3
*Dissolved Kjeldahl nitrogen	Filtration & digestion followed by electrode method	1979 EPA methods, p. 351.4
Dissolved nitrate-nitrite nitrogen	Filtration followed by cadmium reduction	1979 EPA methods, p. 353.3
Dissolved Phosphorus	Filtration followed by automated ascorbic acid method	1979 EPA methods, p. 365.1
Fecal Coliform	Membrane Filter	Std. methods, p. 937
Lead	Digestion followed by atomic absorption using furnace	1979 EPA methods, p. 239.2
Dissolved Lead	Filtration followed by digestion and atomic absorption using furnace	1979 EPA methods, p. 239.2
Magnesium	Digestion followed by atomic absorption	Std. methods, p. 148
Oil & Grease	Separatory Funnel Extraction	1979 EPA methods, p. 413.1
pH	Electrometric method	1979 EPA methods, p. 150.1
Potassium	Digestion followed by atomic absorption	1979 EPA methods, p. 258.1
Sodium	Digestion followed by atomic absorption	1979 EPA methods, p. 273.1
Specific Conductance	Conductivity Bridge	Std. methods, p. 71
Sulfate	Turbidimetric	Std. methods, p. 496
Suspended Solids	Glass Fiber Filtration	1979 EPA methods, p. 160.2
*Total Kjeldahl nitrogen	Digestion followed by Electrode method	1979 EPA methods, p. 351.4
Total Phosphorus	Automated ascorbic acid method	1979 EPA methods, p. 365.1
Total Residue	Gravimetric	1979 EPA methods, p. 160.3

TABLE XII. -- Continued

Parameter	Method	Reference**
Turbidity	Nephelometric	1979 EPA methods, p. 180.1
Volatile Suspended Solids	Gravimetric	1979 EPA methods, p. 160.4

*No distillation prior to analysis.
**For EPA methods see reference No. 31.
For Standard Methods see reference No. 32.

Quality Assurance

A quality assurance (QA) plan was developed for this project by Ms. Marsha Smith and was approved by EPA in January 1981. Copies of this plan are on file with the EPA Region VIII Quality Assurance Coordinator, Denver, Colorado; or it can be obtained from the author.

Care was exercised to insure the integrity of the data. Standards (both known and unknown), duplicates, blanks, and spikes were routinely analyzed. Values which did not satisfy the QA requirements were not entered into the data base.

Quality control samples were analyzed quarterly during the project in order to monitor the procedures being used. The data collected from these analyses has been used to calculate the accuracy and precision of the analytical results reported by the Rapid City NURP. These data are reported in TABLE XIII.

Concern was expressed during the course of the project because some NURP projects were analyzing for total lead and some for total recoverable lead and both results were being entered into STORET under the same code number.

In order to determine if there were significant differences between the results obtained from these two different procedures for the type of samples being analyzed by our laboratory, 12 samples were run by each digestion method. The results obtained are given in TABLE XIV.

It was expected that, if differences existed, the total recoverable lead values would be lower. However, as can be seen from TABLE XIV, in all cases except one the total lead values are lower. These differences could be caused by a loss of lead during the more vigorous digestion procedure required for the total lead analysis. However, further tests would have to be run in order to determine the cause for the differences.

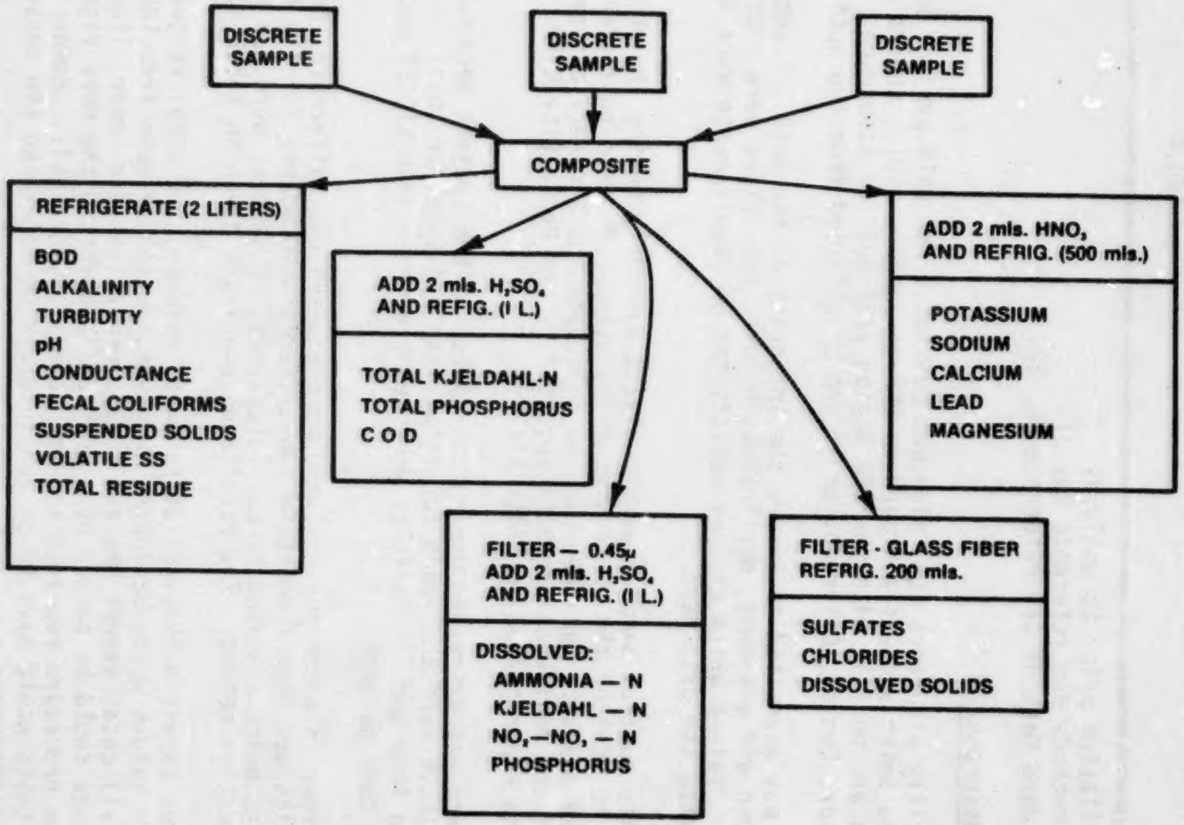
DISCRETE SAMPLE
DISCRETE SAMPLE
DISCRETE SAMPLE
COMPOSITE
REFRIGERATE (2 LITERS)
BOD
ALKALINITY
TURBIDITY
pH
CONDUCTANCE
FECAL COLIFORMS
SUSPENDED SOLIDS
VOLATILE SS
TOTAL RESIDUE
ADD 2 mls. H_2SO_4 AND REFIG. (I L.)
TOTAL KJELDAHL-N
TOTAL PHOSPHORUS
C O D
FILTER — 0.45μ ADD 2 mls. H_2SO_4 AND REFRIG. (I L.)
DISSOLVED:
AMMONIA — N
KJELDAHL — N
NO_2—NO_3 — N
PHOSPHORUS
FILTER - GLASS FIBER REFRIG. 200 mls.
SULFATES
CHLORIDES
DISSOLVED SOLIDS
ADD 2 mls. HNO_3 AND REFRIG. (500 mls.)
POTASSIUM
SODIUM
CALCIUM
LEAD
MAGNESIUM

Figure 4. -- Preservation and Treatment of Samples

TABLE XIII. -- Accuracy and Precision Data

Parameter	Accepted Value (mg/ℓ)	Number of Analyses	Average Reported Value (mg/ℓ)	Per-cent Bias	Standard Deviation
Alkalinity	16.0	7	15.3	- 4.4	1.08
(mg/ℓ $CaCO_3$)	73.7	7	71.7	- 2.7	2.03
Ammonia-N	0.19	15	0.20	+ 5.3	0.12
(mg/ℓ)	1.3	14	1.36	+ 4.6	0.044
BOD (5-day)	2.4	4	2.4	0	0.29
(mg/ℓ)	100.6	4	105	+ 4.4	30.8
Calcium	6.7	10	6.4	- 4.5	0.25
(mg/ℓ)	32.0	11	31.3	- 2.2	0.80
COD	10.4	8	8.8	-15.4	1.0
(mg/ℓ)	192.7	8	188	- 2.4	4.3
Chloride	20.5	7	19.9	- 2.9	0.88
(mg/ℓ)	70.2	7	69.4	- 1.1	0.85
Dissolved	66	7	73	+10.6	8.4
Solids (mg/ℓ)	277	7	294	+ 6.1	24
Kjeldahl-N	0.52	12	0.48	- 7.7	0.049
(mg/ℓ)	4.12	11	4.15	+ 0.7	0.22
Lead	18	10	14.6	-18.9	2.8
(mg/ℓ)	80	10	75.4	- 5.8	7.3
	250	10	256	+ 2.4	37
Magnesium	2.4	10	2.36	- 1.7	0.07
(mg/ℓ)	7.1	10	6.99	- 1.6	0.10

TABLE XIII. -- Continued

Parameter	Accepted Value (mg/ℓ)	Number of Analyses	Average Reported Value (mg/ℓ)	Per-cent Bias	Standard Deviation
Nitrate-Nitrite Nitrogen (mg/ℓ)	0.31	10	0.31	0	0.02
	1.59	9	1.60	+ 0.6	0.12
Oil and Grease (mg/ℓ)	12	9	13.1	+10.8	1.1
	20	9	19.6	- 2.0	1.2
Phosphorus (mg/ℓ)	0.14	21	0.126	-10.0	0.01
	0.93	21	1.0	+ 7.5	0.06
Potassium (mg/ℓ)	1.7	10	1.72	+ 1.2	0.02
	7.2	10	7.20	0	0.17
Sodium (mg/ℓ)	7.0	7	6.91	- 1.3	0.085
	40.0	6	39.4	- 1.5	0.57
Specific Conductance (μmhos/cm)	125	9	131	+ 4.8	5.2
	479	9	491	+ 2.5	29
Sulfate (mg/ℓ)	12.0	9	11.5	- 4.2	0.41
	75.0	10	74.8	- 0.3	1.4
Suspended Solids (mg/ℓ)	29.1	5	32.4	+11.3	1.9
	156	10	164	+ 5.1	12
	534	11	540	+ 1.1	28
Volatile Suspended Solids (mg/ℓ)	44.8	10	48.5	+ 8.3	6.0
	296	11	304	+ 2.7	26

TABLE XIV. -- Comparison of Results of Lead Analysis

Sample ID No.	Total Recoverable Lead (ug/ℓ)	Total Lead (ug/ℓ)
29-4	84	64
29-5	82	56
29-6	164	158
31-4	66	57
31-5	40	36
31-6	196	200
32-2	40	36
32-3	45	40
32-4	169	116
32-5	127	98
33-4	50	46
33-5	36	31

Miscellaneous Methods

Oil and Grease

Samples were collected for oil and grease determinations from Sta. No. 6. The glass sampling container was thoroughly cleaned and finally cleaned with freon (Flurocarbon-113) in the laboratory. The container had a wide mouth which allowed the analyst access to all surfaces during testing. Only discrete samples were collected and tested for oil and grease.

Priority Pollutants

Special sampling container preparation was necessary for the priority pollutant samples. Sampling and shipping procedures specified by the contract laboratory were closely followed. These procedures are explained in detail by Systems, Science, and Software (33).

Samples were iced and sent by air freight to the laboratory in San Diego. Time between sampling and arrival at the laboratory normally exceeded 24 hours but was less than 48 hours. Blind duplicates were sent to the laboratory to assist in evaluating the data.

Special Metals Survey

The Rapid City NURP participated in a special metals survey through an EPA contract with Versar, Inc. of Springfield, Virginia. Data collected under this survey are reported elsewhere in this report.

The extra metals samples were subsets of samples composited for the normal testing program. Nitric acid was added as a preservative to the samples prior to shipping to the contractor. Collection and shipping procedures were based on a document prepared by Frederick and Healy (34).

V. RESULTS

General

The hydrologic and water quality data generated during this three-year study are listed in Appendix A. This section will be used to summarize the more important trends and characteristics of these data as well as interpreting their most probable meaning.

The reader is reminded that Sta. No. 1 through 5 are in-stream stations located on Rapid Creek with continuous flow at each station. Sta. No. 1 represents the background station before urban runoff enters the stream, and Sta. No. 5 is the lowest downstream sampling station on the creek. The effluent from Site No. 6 drains into Rapid Creek downstream from Sta. No. 5 and represents the single largest urban discharge to the creek. Flow at Sta. No. 6 occurs predominately only during a runoff event, but a small (usually unmeasurable), baseline flow was normally present. Sta. 56 is the theoretical, downstream station used to reflect the quality of the stream as it leaves the urban area. Data for Sta. 56 were obtained by mixing the loads generated at Sta. No. 5 and No. 6.

Sampling Summary

A detailed summary of the discharge at the six sampling stations is given in Table 15 in Appendix A. Shown below in Table XV is a summary of the runoff events which were sampled over the three years. The rainfall distribution across Rapid City would frequently cause a rise in streamflow at some stations while only a negligible rise in discharge would occur at other stations. In as much as possible, runoff events which would produce an increase in discharge at all six stations were sampled.

In addition to the runoff events listed in Table XV, nine sets of baseline samples were collected when runoff was not occurring. These sets were obtained on May 21, June 3, July 9, and September 29 during 1980; February 21, April 29, and June 24 during 1981; and on April 28 and June 23 during 1982.

Hydrology

Hydrologic data (precipitation, streamflow, and runoff, are presented in detail in Appendix A. The statistical analysis of these data is also included in Appendix A, written by USGS personnel. The more pertinent hydrologic findings are included in this section.

Streamflow

A complete statistical analysis of long term streamflow data for Rapid Creek can be found in Appendix A. The analysis is based on records obtained from October of 1963 until September of 1981 for two USGS gaging stations, No. 6412500 and 6414000. Sta. No. 6412500 is designated as "Rapid Creek

TABLE XV. -- Sampling Summary

Runoff Event No.	Date	Stations Sampled	Area-Averaged Precipitation, inches
1	6/14/80	1, 2, 3, 4, 5, 6	E 0.6
2	6/18/80	1, 2, 3, 4, 5, 6	E 0.2
3	7/12/80	1, 2, 3, 4, 5, 6	E 0.8
4	7/20/80	1, 2, 3, 4, 5, 6	E 0.3
5	7/25/80	1, 2, 3, 4, 5, 6	E 0.3
6	8/20/80	1, 2, 3, 4, 5, 6	E 0.2
7	10/15/80	1, 2, 3, 4, 5, 6	E 2.12
8	4/03/81	6	0.08
9	4/21/81	6	0.17
10	5/02/81	5, 6	0.27
11	5/06/81	1, 2, 3, 4, 5	0.34
12	5/07/81	4, 5, 6	0.14
13	5/12-13/81	6	0.23
14	5/16-18/81	1, 2, 3, 4, 5, 6	2.99
15	5/22-23/81	5, 6	0.70
16	6/03/81	3, 4, 5, 6	0.14
17	7/01-02/81	1, 2, 3, 4, 5, 6	0.39

cont'd on following page --

TABLE XV. -- Sampling Summary (cont'd)

Runoff Event No.	Date	Stations Sampled	Area-averaged Precipitation, inches
18	7/13/81	1, 2, 3, 4, 5, 6	0.39
19	7/18/81	3, 5, 6	0.43
20	7/23/81	1, 2, 3, 4, 5, 6	0.25
21	7/25/81	1, 2, 3, 4, 5, 6	2.59
[c]22	10/05/81	1, 3, 5, 6	0.48
[a]23	12/20/81	1, 2, 3, 4, 5, 6	E 0.3
[a]24	3/07-08/81	1, 2, 3, 4, 5, 6	E 0.3
[a]25	3/09-10/81	1, 2, 3, 4, 5, 6	0
26	5/10/82	1, 2, 3, 4, 5, 6	0.66
27	5/13-14/82	3, 4, 5, 6	b
[c]28	5/17/82	1, 3, 5, 6	0.16
29	5/19-20/82	1, 2, 3, 4, 5, 6	1.10
30	5/28/82	3, 4, 5, 6	b
31	6/15/82	1, 2, 3, 4, 5, 6	0.30
32	6/16/82	1, 2, 3, 4, 5, 6	0.67
33	7/08/82	1, 2, 3, 4, 5, 6	0.26

E = Estimated value

a = Snowmelt Event

b = Normal data collection sacrificed for automatic sampler calibration

c = Normal data collection sacrificed to obtain priority pollutant samples above Canyon Lake" by USGS and corresponds to Sta. No. 1 for the NURP study. USGS Sta. No. 6414000 is designated as "Rapid Creek at Rapid City" and corresponds to Sta. No. 3 for the NURP study.

The streamflow in Rapid Creek is regulated by the discharge from Pactola Reservoir, except during runoff events. Pactola Reservoir has been in operation since 1963. The distribution of the streamflow is shown in Figure 5 for the months of April through September. The median discharge is about 55 cfs at Sta. No. 1 and about 65 cfs at Sta. No. 3. The increase in downstream flow shows the effects of water from Cleghorn Spring, Lime Creek, and some artesian wells near the cement plant.

Tables XVI and XVII give statistics for the mean monthly discharges at the two stations. Notice that the discharge data are usually positively skewed.

Precipitation

Detailed precipitation data are found under the heading of "Meteorological Data" in Appendix A by USGS. Two long-term precipitation records for this area are available, both from National Oceanic and Atmospheric Administration (NOAA) weather stations. One station (No. 396947-05) is located at the Sioux Sanitarium in western Rapid City, while the other (No. 396937-05) is located at the Rapid City Regional Airport about 7 miles east-southeast of the city.

The mean monthly precipitations for the two stations are illustrated on Figure 6. The majority of the precipitation occurs as rainfall between April and September, with June having the highest mean monthly value. Usually the station in western Rapid City shows more precipitation than the station at the airport. This difference is attributed to the precipitation distribution during upslope storms as the Sioux Sanitarium station is at a higher elevation.

Duration of precipitation and amount of precipitation are characterized for data from the station at the Rapid City Airport in Figures 7 and 8. Hourly data for this statistical characterization were not available from the Sioux Sanitarium location.

Table XVIII lists the total rainfall for the runoff events sampled in this study by subbasin. The rainfall amounts were obtained using the Thiessen Polygon method as described in Appendix A. West Rapid City represents the subbasin with contributing area between Sta. No. 1 and 2, Deadwood Avenue is the subbasin between Sta. No. 2 and 3, the Central Business District is the subbasin between Sta. No. 3 and 4, and East Rapid City is the contributing subbasin between Sta. No. 4 and 5. Sta. No. 6 is located on the Meade Street drainage channel which drains the Robbinsdale watershed.

Runoff

Table XIX summarizes the runoff volumes for the different subbasins for each storm event. The volumes include the runoff generated

TABLE XVI. -- Statistics on monthly means for the station Rapid Creek above Canyon Lake for the period October 1, 1963 to September 30, 1981

	Jan.	Feb.	Mar.	Apr.	May	June
Mean, cfs	11.50	13.10	21.40	43.60	102.00	135.00
Variance	20.40	24.50	248.00	1,267.00	5,470.00	12,560.00
Standard deviation, cfs	4.52	4.95	15.70	35.60	74.00	112.00
Skewness	.62	1.74	1.72	2.06	1.39	1.59
Coefficient of variation, %	39.	38.	73.	82.	72.	83.
	Percentage of average value					
	2.06	2.33	3.82	7.76	18.20	24.10
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean, cfs	87.90	56.40	39.70	23.60	15.10	12.00
Variance	1,782.00	344.00	206.00	391.00	55.20	26.70
Standard deviation, cfs	42.20	18.50	14.30	19.80	7.43	5.17
Skewness	1.53	.62	.51	2.41	1.17	1.04
Coefficient of variation, %	48.	33.	36.	84.	49.	43.
	Percentage of average value					
	15.70	10.00	7.06	4.21	2.69	2.14

TABLE XVII. -- Statistics on monthly means for the station Rapid Creek at Rapid City for the period October 1, 1963 to September 30, 1981

	Jan.	Feb.	Mar.	Apr.	May	June
Mean, cfs	28.20	30.20	38.20	61.40	118.00	156.00
Variance	41.70	52.10	225.00	1,523.00	6,047.00	17,550.00
Standard deviation, cfs	6.46	7.22	15.00	39.00	77.80	132.00
Skewness	-.05	.73	1.67	1.97	1.52	1.59
Coefficient of variation, %	23.	24.	39.	64.	66.	85.
	Percentage of average value					
	3.75	4.01	5.08	8.17	15.70	20.80
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean, cfs	96.90	64.70	52.40	39.80	34.20	31.00
Variance	1,853.00	262.00	222.00	335.00	68.00	41.30
Standard deviation, cfs	43.00	16.20	14.90	18.30	8.25	6.42
Skewness	1.53	.65	.52	2.20	1.38	.32
Coefficient of variation, %	44.	25.	28.	46.	24.	21.
	Percentage of average value					
	12.90	8.68	6.97	5.30	4.55	4.13

TABLE XVIII. -- Rainfall amounts of sampled runoff events, area-averaged by subbasins and by study area, June 1980-July 1982, Rapid City, South Dakota

Runoff event number	Area-averaged rainfall, in inches					
	West Rapid City	Deadwood Avenue	Central Business District	East Rapid City	Robbinsdale	Rapid City study area
1	E 0.6	E 0.7	E 0.5	E 0.5	E 0.5	E 0.6
2	E .2	E .2	E .2	E .2	E .2	E .2
3	E .9	E .7	E .8	E .5	E .8	E .8
4	E .3	E .3	E .3	E .3	E .3	E .3
5	E .3	E .2	E .3	E .2	E .2	E .3
6	E .2	E .2	E .2	E .2	E .2	E .2
7	E 2.12	E 2.10	2.30	E 2.22	E 2.18	E 2.12
8	.09	.09	.05	.04	.05	.08
9	.18	.14	.14	.15	.17	.17
10	.23	.34	.37	.35	.33	.27
11	.37	.30	.29	.31	.18	.34
12	.21	.20	.18	.18	.19	.14
13	.23	.21	.27	.28	.23	.23
14	3.30	2.90	2.18	1.87	2.20	2.99
15	.73	.74	.62	.54	.59	.70
16	.07	.17	.32	.34	.29	.14
17	.42	.35	.29	.34	.28	.39
18	.40	.40	.35	.31	.35	.39

TABLE XVIII. -- Continued

	Area-averaged rainfall, in inches					
Runoff event number	West Rapid City	Deadwood Avenue	Central Business District	East Rapid City	Robbinsdale	Rapid City study area
19	.42	.40	.39	.41	.63	.43
20	.09	.25	.82	.94	.33	.25
21	2.68	2.29	2.18	2.33	3.12	2.59
22	.46	.49	.52	.54	.54	.48
[a]23-SM	E .3	E .3	E .3	E .3	E .3	E .3
[a]24-SM	E .3	E .3	E .3	E .3	E .3	E .3
[a]25-SM	0	0	0	0	0	0
26	.62	.69	.74	.73	.78	.66
[b]27	--	--	--	--	--	--
28	.11	.21	.21	.19	.44	.16
29	1.02	1.14	1.25	1.21	1.46	1.10
[b]30	--	--	--	--	--	--
31	.31	.25	.27	.33	.31	.30
32	.75	.59	.48	.40	.54	.67
33	.30	.25	.16	.11	.20	.26

E Estimated value.

[a] Snowmelt event. Precipitation amount estimated based on temperature and precipitation data obtained by the National Oceanic and Atmospheric Administration. Events 24 and 25 are two periods of melting from a single snowfall.

[b] Runoff event used for automatic sampler calibration. Rainfall data not necessary.

TABLE XIX. -- Runoff Volumes[a] by Subbasin, Ac-ft

Runoff Event No.	West Rapid City	Deadwood Avenue	Central Business District	East Rapid City	Robbins-dale
1	10.4	12.6	31.8	34.7	12.4
2	1.86	2.31	5.91	8.68	2.78
3	22.6	34.4	52.7	46.3	8.06
4	8.68	14.0	22.9	19.2	4.46
5	8.93	12.4	22.9	17.9	3.33
6	2.60	4.34	8.68	7.68	2.10
7	76.3	114	168	190	48.7
8	0	0	∿0	∿0	∿0
9	1.65	2.93	6.61	4.67	1.72
10	3.17	6.32	24.3	32.6	5.20
11	3.97	8.06	14.2	16.2	2.87
12	3.51	5.58	8.64	13.5	3.89
13	0	8.2	17.2	17.6	4.17
14	169	217	309	370	70.9
15	10.7	20.1	35.5	35.5	11.2
16	1.07	2.07	13.1	16.1	5.16
17	11.2	28.0	35.8	37.7	4.05
18	10.6	20.0	23.3	28.2	4.83

cont'd on next page --

TABLE XIX. -- Continued

Runoff Event No.	West Rapid City	Deadwood Avenue	Central Business District	East Rapid City	Robbinsdale
19	11.2	17.9	29.4	35.7	10.4
20	2.42	5.97	73.0	116	8.33
21	140	193	318	372	101
22	9.83	12.6	19.3	26.8	6.02
23	b	b	b	b	b
24	b	b	b	b	b
25	b	b	b	b	b
26	12.9	30.4	54.5	61.3	17.4
27	c	c	c	c	c
28	0.80	2.73	11.3	12.4	9.87
29	37.5	69.7	125	145	51.4
30	c	c	c	c	c
31	5.79	6.36	19.0	19.0	8.71
32	23.7	36.7	49.1	51.0	14.5
33	6.2	8.66	12.4	13.0	3.04

a Runoff volumes include streamflows from upstream subbasins, i.e.,
Runoff volume = (Mean flow - baseline flow) runoff duration.

b Snowmelt runoff - Accurate discharge data unavailable.

c Normal data collection sacrificed for automatic sampler calibration.

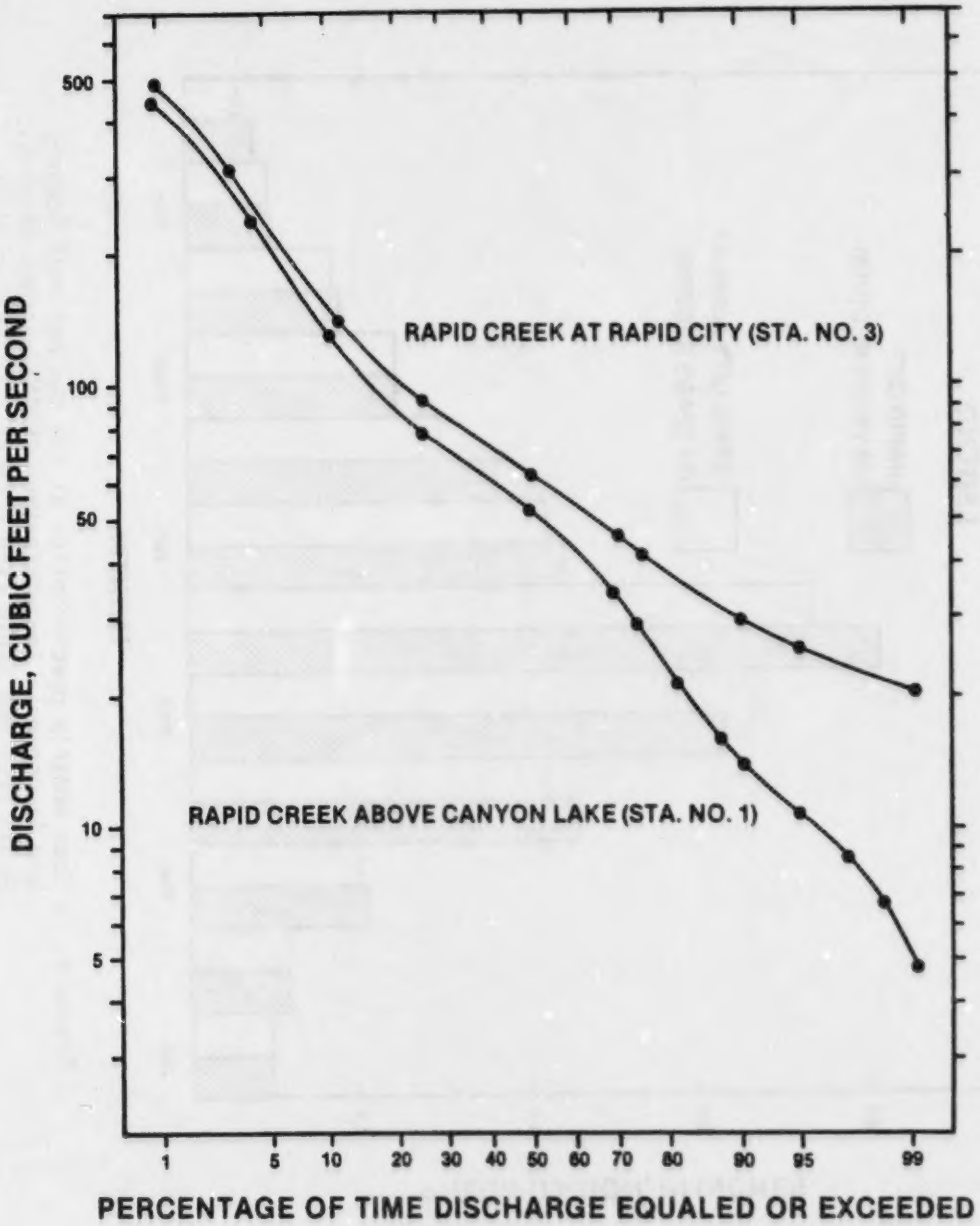

Figure 5. -- Distribution of mean daily discharge measured at the gaging stations, Rapid Creek above Canyon Lake and Rapid Creek at Rapid City, for the months April through September, for the period April 1, 1964 through September 30, 1981.

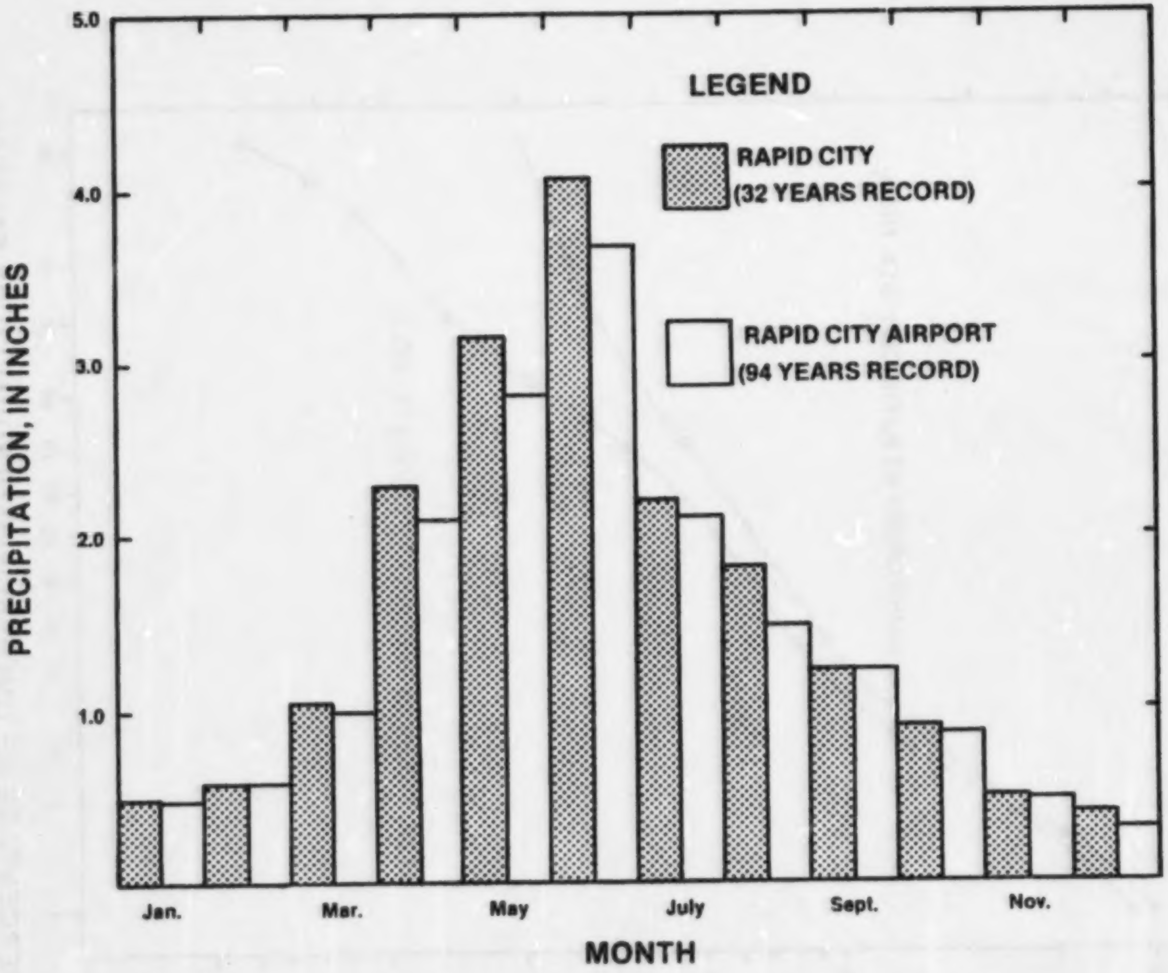

Figure 6. -- Mean monthly precipitation at the two National Oceanic and Atmospheric Administration (NOAA) weather stations, Rapid City and Rapid City Airport for the period of record.

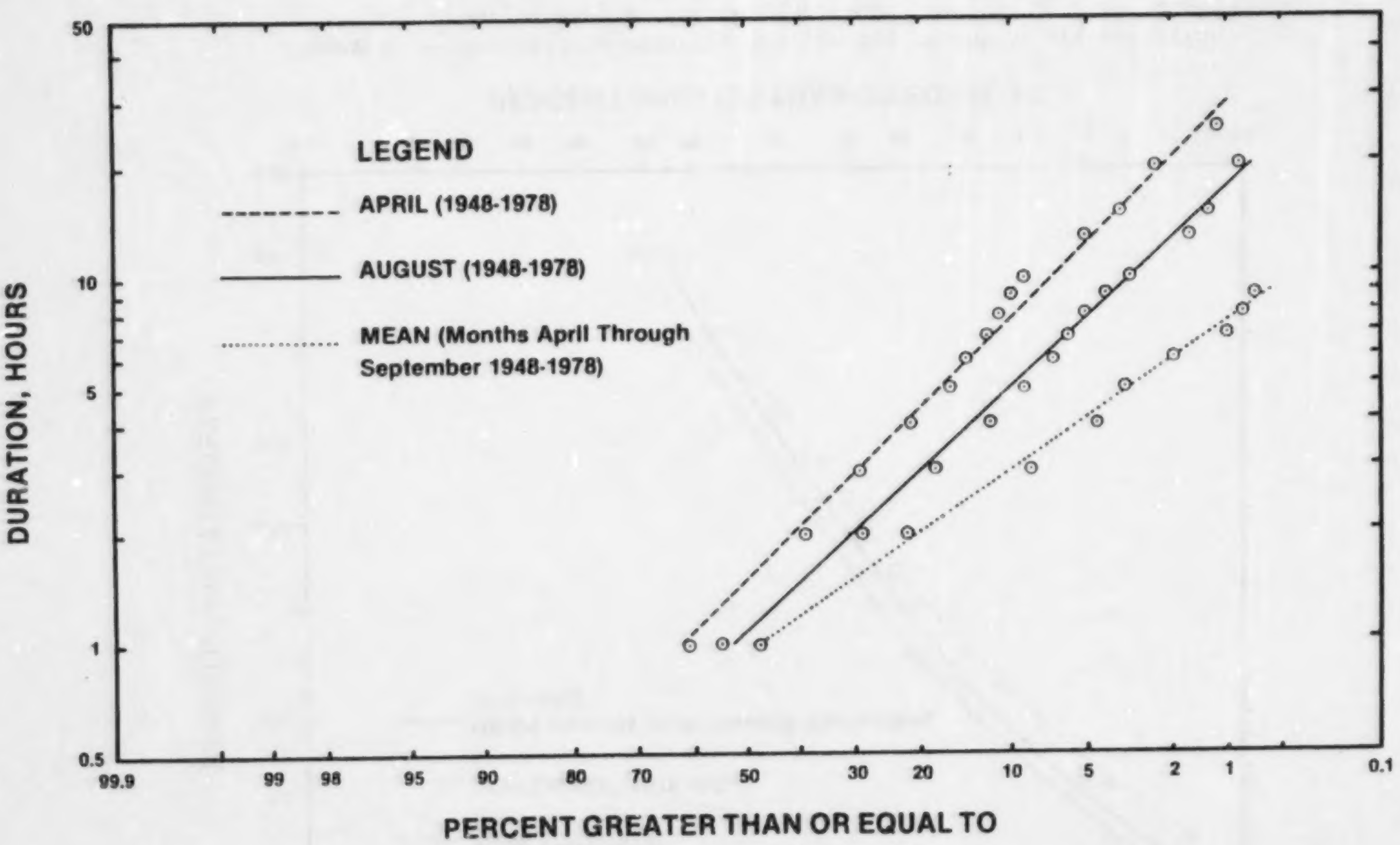

Figure 7. -- Probability distribution for the duration of precipitation events, for the individual months, April and August, and the overall mean for the months, April through September, measured at the NOAA weather station, Rapid City Airport for the years 1948-1978.

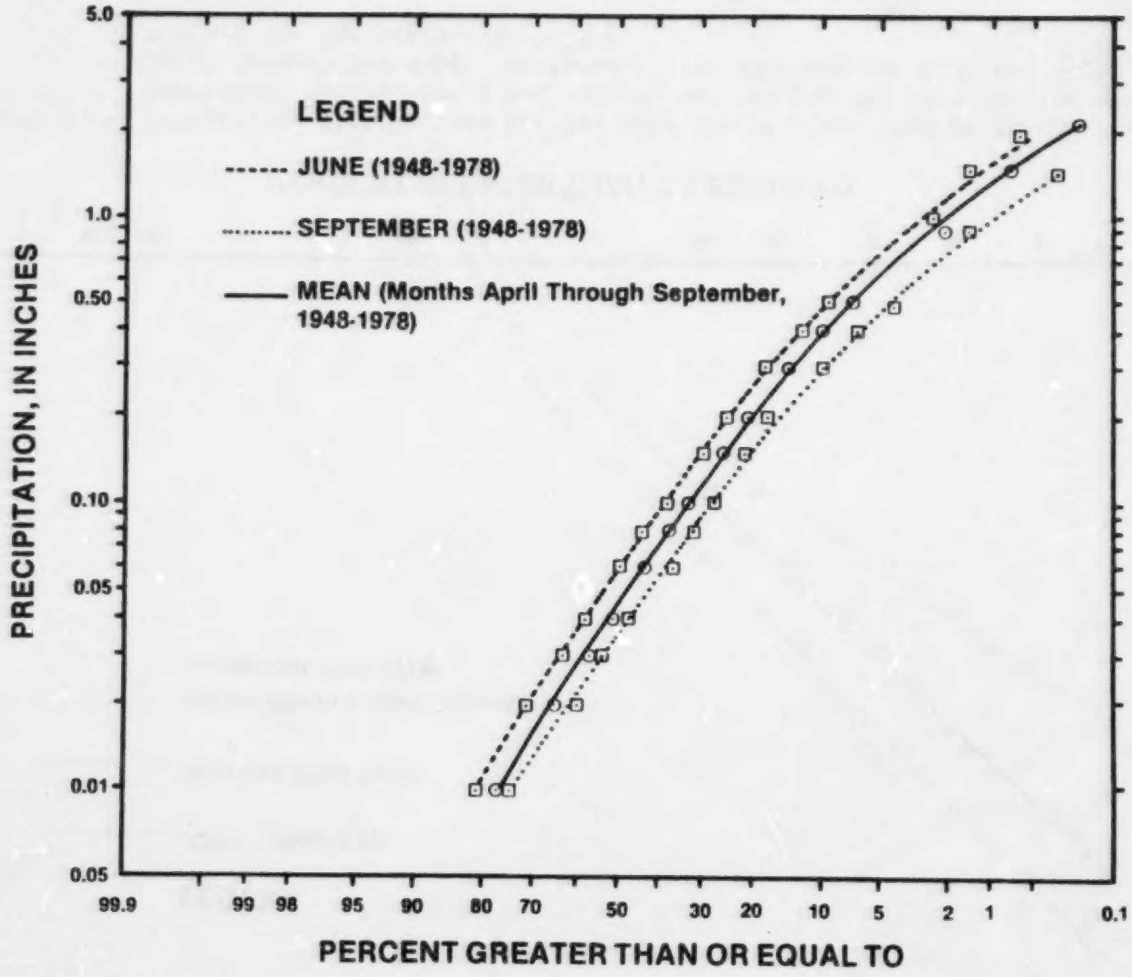

Figure 8. -- Probability distribution for the amount of precipitation during events, for the individual months, June and September, and the overall mean for the months, April through September, measured at the NOAA weather station, Rapid City Airport for the years 1948-1978.

from upstream, but excludes the base flow at each station. Table XX summarizes the runoff from the same events, but excludes both the base flow and the upstream runoff. It is difficult to arrive at general conclusions for these data because of the variations in precipitation between subbasins for the same event.

Runoff events No. 7 (late fall) and 14 (early spring) are representative of storms which generated substantial precipitation over the entire study area. Even then the precipitation was quite variable, with subbasins receiving from 62.5 percent to 110 percent of the average (See Table XVIII). Event No. 20 would seem to be typical of many of the thunderstorms the study area received. Precipitation varied from 0.09 inches to 0.94 inches while the average over the study area was 0.25 inches; thus representing 36 percent and 37.6 percent of the average. The runoff volumes for events No. 7 and 14 show how the streamflow increases as Rapid Creek flows through town (Table XIX), and that each subbasin contributed a substantial discharge to the stream (Table XX). Event No. 20, on the other hand, illustrates the variability that can occur in that almost all the runoff was generated on the Central Business District and East Rapid City subbasins.

Some negative values were obtained for the East Rapid City subbasin when the data were reduced for Table XX (Events No. 3, 4, 5, 6, and 9). Theoretically these negative values are not possible, but they were usually within the normal limits of discharge measurements. The runoff volumes contributed by the East Rapid City subbasins represent 7.1, 6.1, 8.1, 2.6, and 20.8 percent of the total volume of flow, respectively, for events No. 3, 4, 5, and 6. The early discharge measurements for this subbasins were complicated because flows in the Hawthorne irrigation ditch were not actually measured until event No. 10. It was not necessary to correlate in-stream flows and water quality data for event No. 9 (20.8 percent error) because only the Robbinsdale watershed was sampled during this storm.

Table XXI gives the runoff: rainfall ratios by subbasins. The total volume of rainfall which fell on each subbasin was divided by the increase in in runoff between sampling stations to obtain the data shown. At first glance, these values seem too low. One would expect urban catchments to have rainfall runoff ratios on the order of 0.10 to 0.50. Normally for small drainage areas this would be true. However, for the much larger areas under consideration in this project; these data are reasonable. Much of the runoff simply does not ultimately find its way to the stream, being retained within depressions enroute.

TABLE XX. -- Runoff Volumes Contributed by Subbasin, Upstream Flow Subtracted, Ac-ft

Runoff Event No.	West Rapid City	Deadwood Avenue	Central Business District	East Rapid City	Robbins-dale
1	8.5	2.2	19.2	2.9	12.4
2	1.86	0.45	3.60	2.77	2.78
3	20.1	11.8	18.3	(-6.4)*	8.06
4	8.02	5.3	8.9	(-3.7)	4.46
5	6.45	3.5	10.5	(-5.0)	3.33
6	1.86	1.74	4.34	(-1.0)	2.10
7	56.1	38	54	22	48.7
8	Negligible Flow Throughout				
9	1.45	1.28	3.68	(-1.9)	1.72
10	2.22	3.15	18.0	8.3	5.20
11	3.97	4.09	6.1	2	2.87
12	2.81	2.07	3.06	4.8	3.89
13	0	8.2	9.0	0.4	4.17
14	102	48	92	61	70.9
15	10.7	9.4	15.4	0.0	11.2
16	1.07	1.00	11.0	3.0	5.16
17	8.7	16.8	7.8	1.9	4.05
18	8.6	9.4	3.3	4.9	4.83
19	8.8	6.7	11.5	6.3	10.4
20	2.42	3.55	67.0	43	8.33
21	120	53	125	54	101
22	9.83	2.8	6.7	7.5	6.02
26	10.2	17.5	24.1	6.8	17.4
28	0.80	1.93	8.6	1.1	9.87
29	28.1	32.2	55	20	51.4
31	5.38	0.57	12.6	0.0	8.71
32	20.6	13.0	12.4	1.9	14.5
33	4.18	2.5	3.7	0.6	3.04

*Impossible values. See text for discussion.

TABLE XXI. -- Runoff/Rainfall Ratios by Subbasin

Runoff Event No.	West Rapid City	Deadwood Avenue	Central Business District	East Rapid City	Robbins-dale	Overall Study Area
1	0.008	0.010	0.126	0.043	0.147	0.028
2	0.005	0.007	0.059	0.103	0.082	0.021
3	0.013	0.041	0.060	-0.095*	0.060	0.024
4	0.015	0.055	0.098	-0.092	0.088	0.029
5	0.012	0.054	0.115	-0.187	0.099	0.023
6	0.004	0.027	0.071	-0.037	0.062	0.017
7	0.015	0.056	0.178	0.074	0.132	0.038
8	Negligible Flow Throughout					
9	0.005	0.028	0.086	-0.097	0.060	0.014
10	0.006	0.029	0.159	0.176	0.093	0.051
11	0.006	0.042	0.070	0.048	0.094	0.021
12	0.008	0.032	0.056	0.201	0.121	0.045
13	0	0.121	0.110	0.011	0.107	0.035
14	0.0003	0.150	0.139	0.243	0.191	0.139
15	0.008	0.039	0.081	0	0.112	0.025
16	0.009	0.018	0.113	0.066	0.105	0.057
17	0.012	0.149	0.088	0.042	0.085	0.038
18	0.012	0.073	0.031	0.118	0.082	0.030
19	0.012	0.052	0.097	0.115	0.097	0.038
20	0.015	0.044	0.269	0.341	0.149	0.186
21	0.004	0.072	0.189	0.173	0.191	0.065
22	0.006	0.018	0.042	0.104	0.066	0.025
26	0.009	0.078	0.107	0.069	0.132	0.043
28	0.0005	0.028	0.134	0.043	0.133	0.052
29	0.016	0.088	0.146	0.123	0.208	0.070
31	0.003	0.007	0.154	0	0.166	0.034
32	0.016	0.068	0.085	0.035	0.159	0.035
33	0.008	0.030	0.077	0.041	0.090	0.005
Mean	0.008	0.052	0.109	0.061	0.115	0.044

*A negative runoff/rainfall ratio is impossible. See text for discussion.

Snowmelt Runoff

Task 6 of the work plan required the monitoring of significant snowmelt events. The winter of 1980-1981 was abnormally dry and did not yield any important snowmelt runoff. Three snowmelt runoff events were sampled during the winter of 1981-1982. In addition, some in-stream conductivity measurements were taken on some minor snowmelt events. A typical conductivity pattern and its relation to discharge is shown in Figure 9. These data are from runoff caused by the melting of about 4½ inches of snow. The weather remained cool and cloudy so it was a slow developing event. Note that a substantial portion of the pollutants, as evidenced by the change in conductivity, were present in the runoff from the first day although the increase in stream flow is barely perceivable. It is also interesting that the maximum temperature for the first day was still below freezing at -3°C.

Accurate discharge measurements were not able to be made because of the diurnal freeze-thaw cycle. Consequently, runoff volumes for snowmelt events were not determined.

The three snowmelt events sampled during the winter of 1981-1982 were event No. 23 on December 20, 1981; event No. 24 on March 7 and 8, 1982; and event No. 25 on March 9 and 10, 1982. Samples were composited by station for event No. 23 and a full set of laboratory determinations were done. For both events No. 24 and 25, a selected set of parameters were determined throughout the hydrograph by testing discrete samples at each station.

A station by station comparison of the composited samples for event No. 23 is given in Table XV. It was not possible to compute theoretical concentrations at Sta. No. 56 because of the limitations on the flow measurements. In general these data show a decrease in water quality as Rapid Creek progresses through the community, and the poorest water quality seems to peak at Sta. No. 4. There appears to be some settling which occurs between Site No. 4 and Site No. 5. Field investigation downstream from Sta. No. 4 would seem to confirm this conclusion. The stream bottom at this location is quite soft and muddy, much more so than either upstream or downstream. Obviously the potential exists for this material to become resuspended should an event occur of sufficient magnitude to cause scour. In-stream water quality standards for normal flow conditions would not be met by the quality present during this snowmelt event.

Figures 10 through 16 show diurnal variations for chloride, sodium, and suspended solids for two snowmelt runoff events during March of 1981. Figures 10 to 14 depict variations for the 5 in-stream stations, while Figures 15 and 16 are for Sta. No. 6 only. Higher flows for event No. 25 correspond to the resulting higher concentrations which were measured.

The background values for all parameters, as measured at Sta. No. 1, were consistently low and nearly constant. Chlorides, for example, remained less than 4 mg/L at Sta. No. 1 while exceeding 100 mg/L at Sta. No. 4 and 5. Data for sodium show the same trend. Even though the City has made efforts to limit the salt it places on the streets, the effects are obvious.

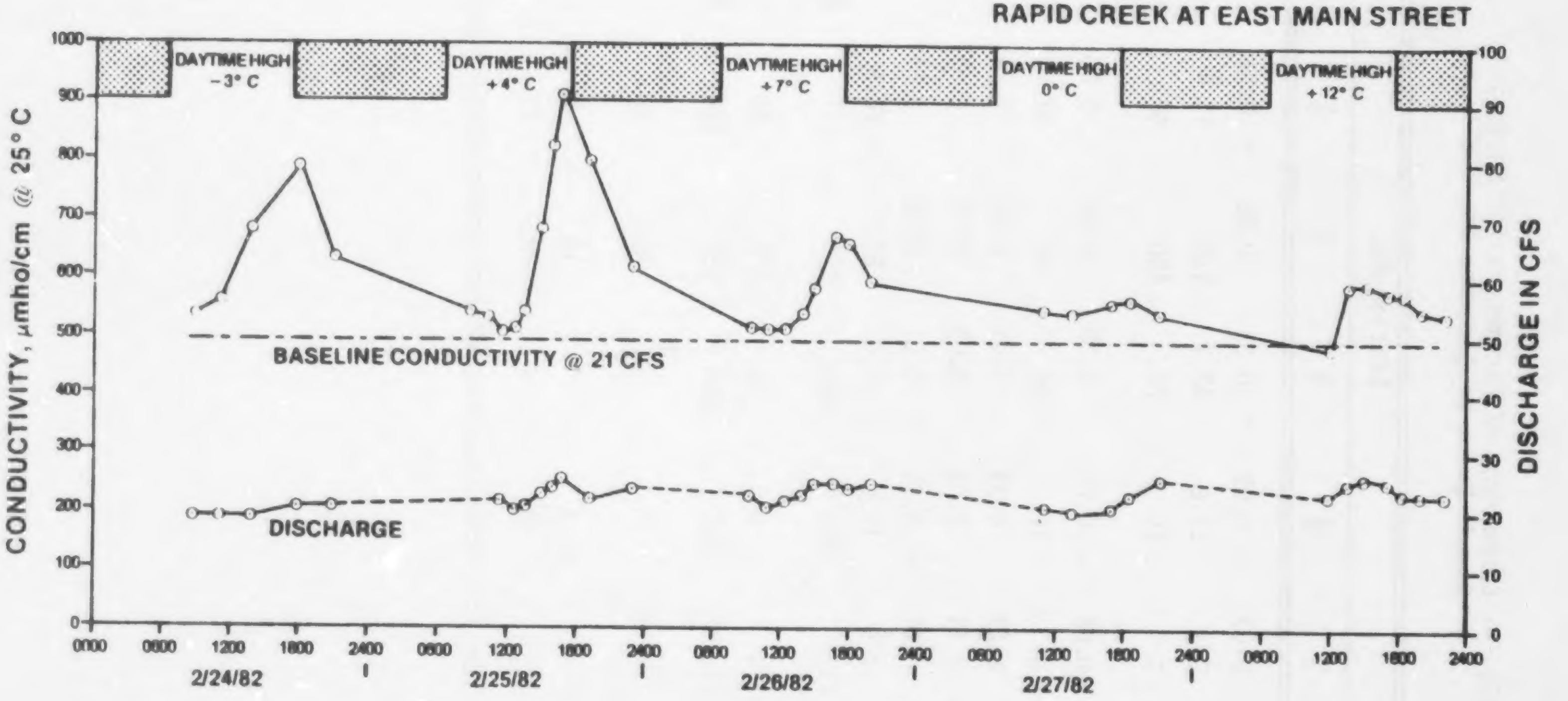

Figure 9. -- Conductivity and discharge at Station 4 during snowmelt runoff, February 24 to February 28, 1982.

TABLE XXII. -- Comparison of Parameters for Snowmelt Runoff Event of December 20, 1981.

Parameter	Station No. 1	2	3	4	5	6
Ammonia, mg/L	< 0.03	< 0.03	< 0.03	0.05	< 0.03	0.38
Cl^-, mg/L	3.7	23.6	42.1	134	40.6	537
Fecal Coliform, No./100 ml	< 3	< 20	< 20	400	40	5,300
TKN, mg/L	< 0.05	< 0.05	0.13	0.29	0.20	2.8
Total Pb, µg/L	< 10	< 10	30	67	32	735
pH, units	8.21	8.39	8.35	8.30	8.24	7.60
Total P, mg/L	< 0.01	0.02	0.03	0.12	0.05	0.56
Diss. P, mg/L	< 0.01	< 0.01	< 0.01	0.03	0.01	0.11
Na, mg/L	4.5	17.0	28.0	87.0	26.8	352
Spec. Cond., µmhos/cm	417	511	653	935	691	2,310
SS, mg/L	< 4	8	18	104	38	520
Total Residue, mg/L	254	324	438	680	494	2,010
Turbidity, NTU	0.50	7.1	15	80	28	450
VSS, mg/L	< 4	< 4	4	18	6	115
COD, mg/L	< 5	9	14	73	22	273

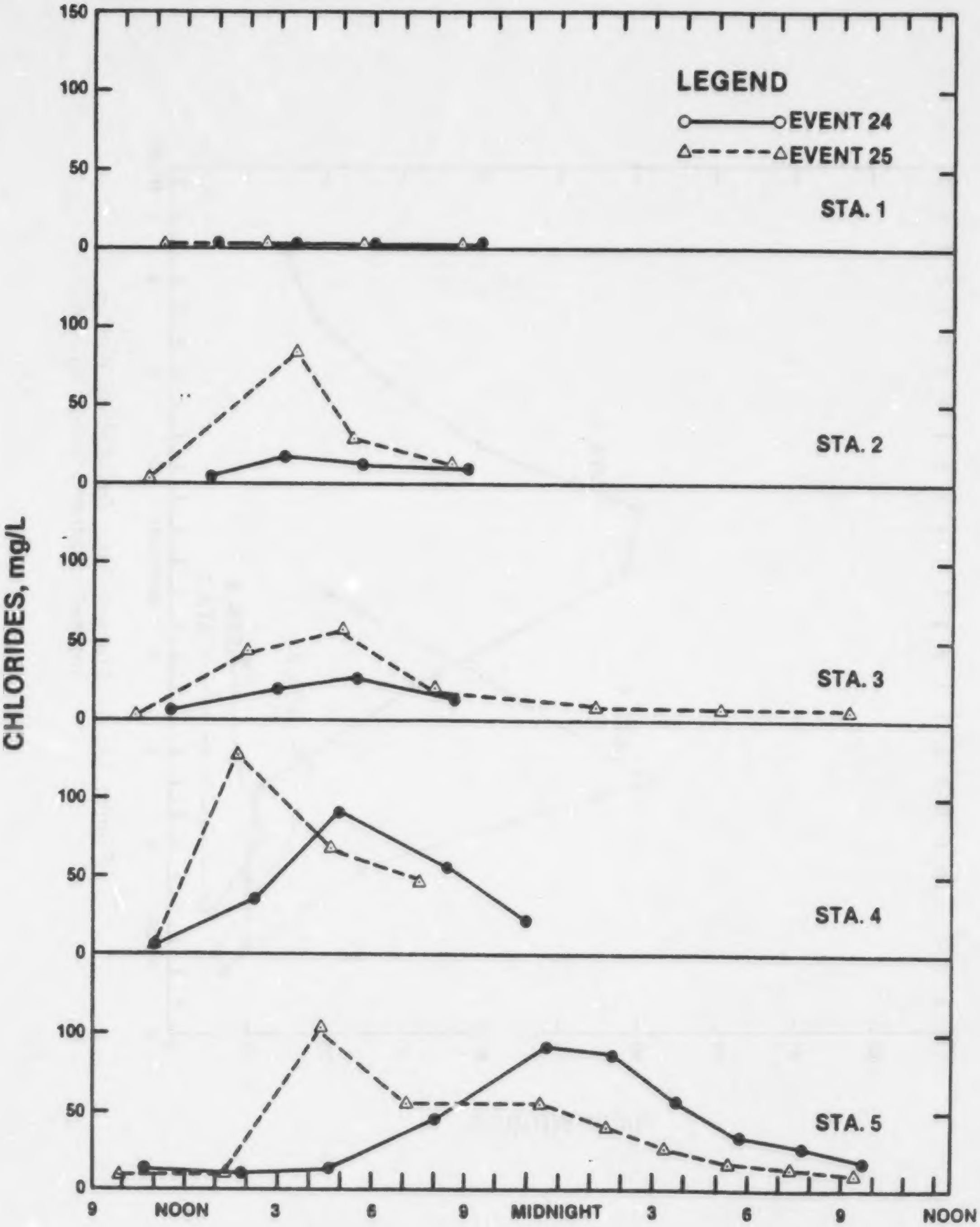

Figure 10. -- Diurnal flux for chloride during snowmelt runoff.

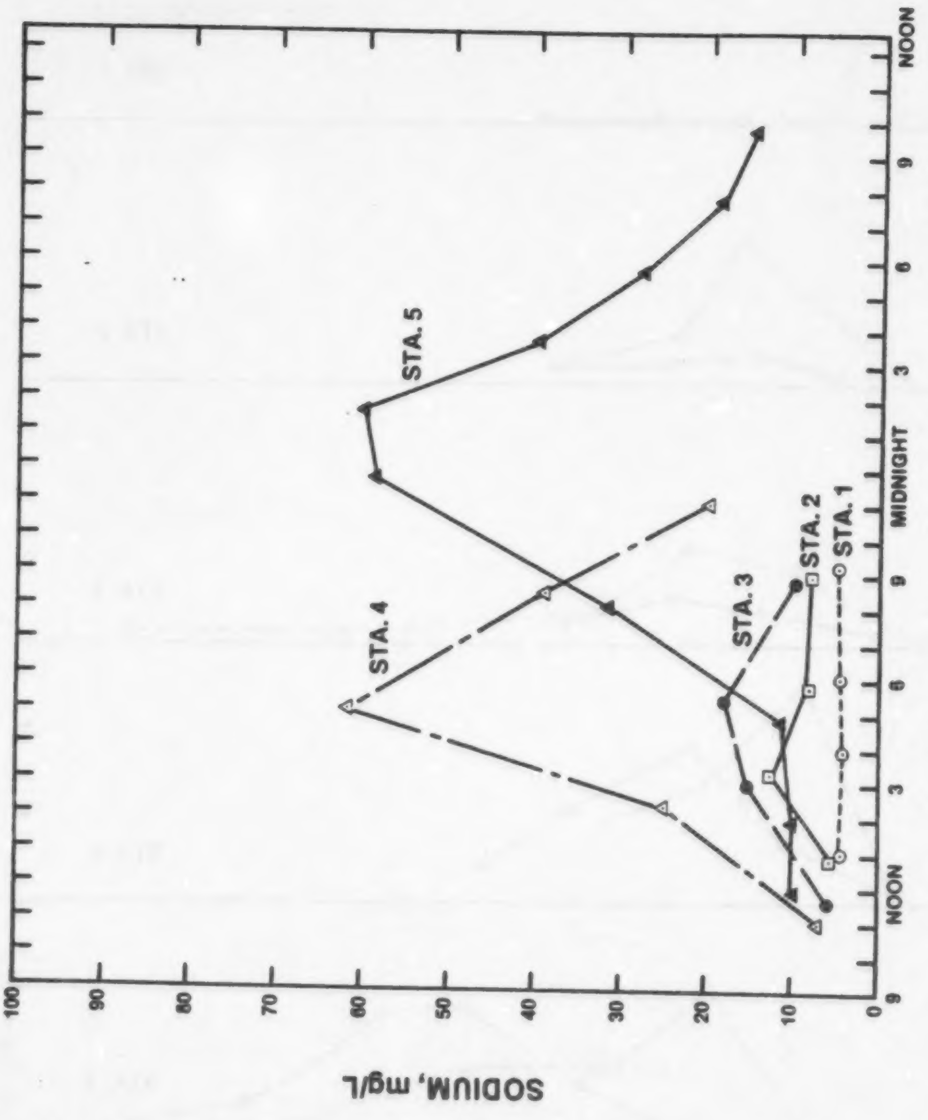

Figure 11. -- Diurnal flux for sodium during snowmelt runoff, Event No. 24.

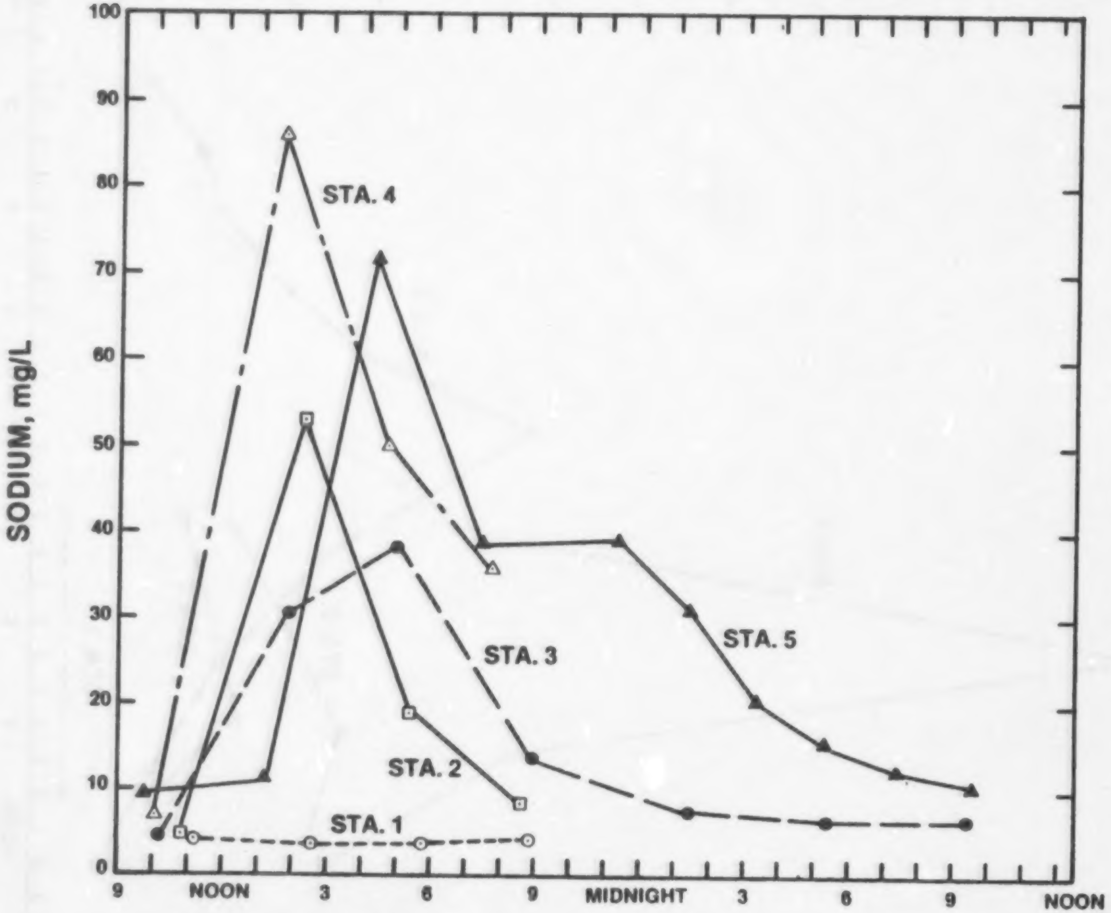

Figure 12. -- Diurnal flux for sodium during snowmelt runoff, Event No. 25.

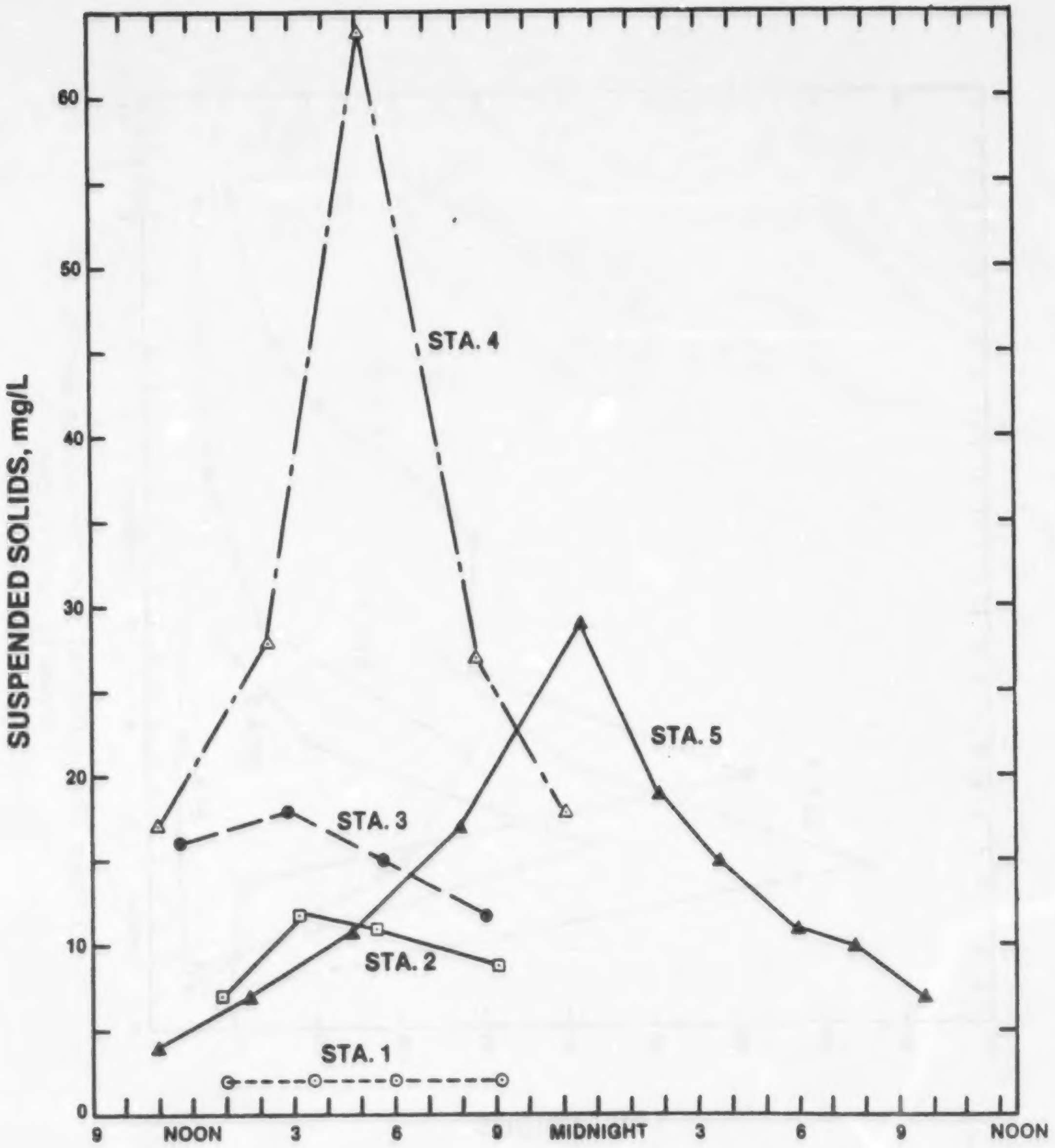

Figure 13. -- Diurnal flux for suspended solids during snowmelt runoff, Event No. 24.

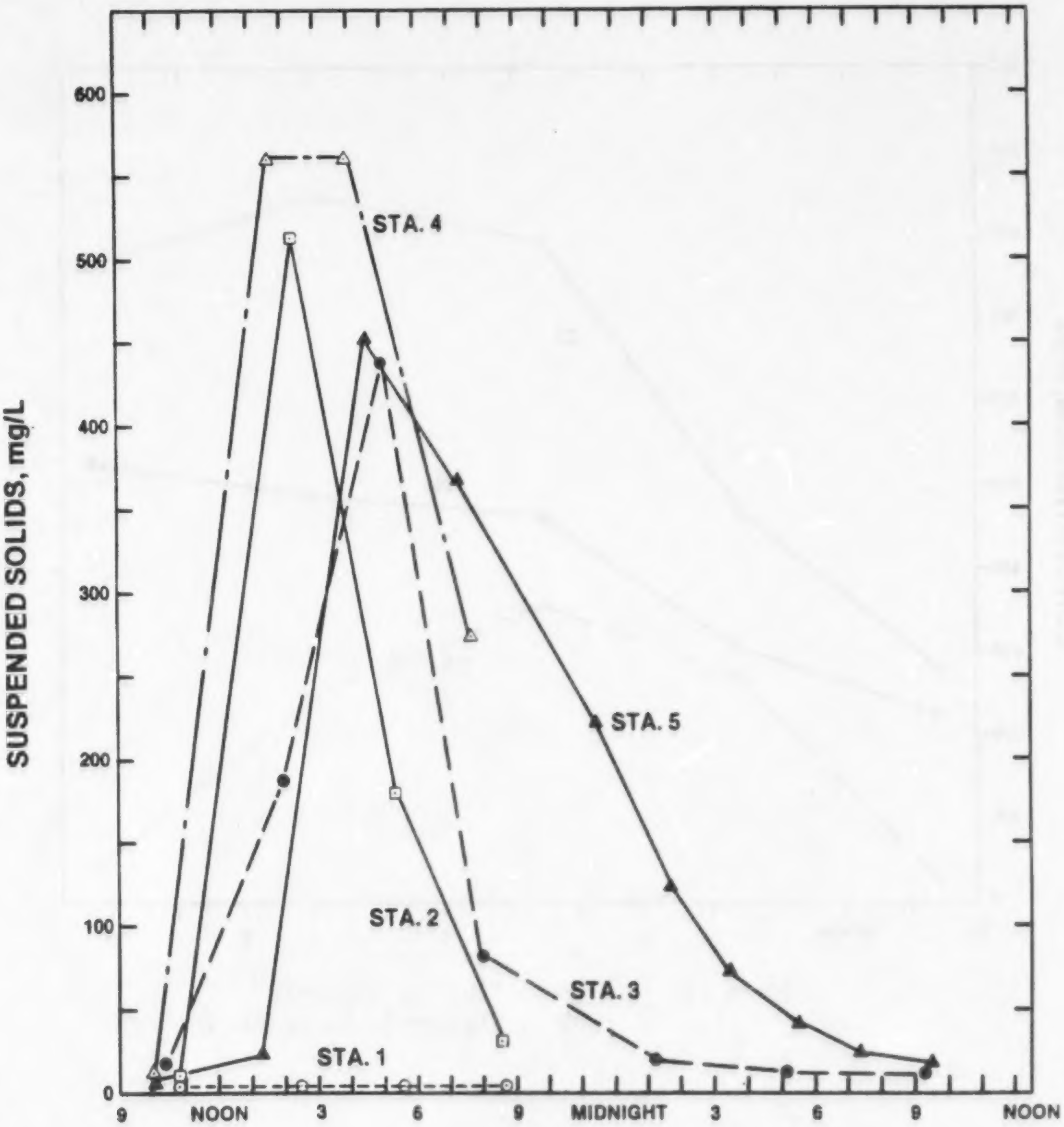

Figure 14. -- Diurnal flux for suspended solids during snowmelt runoff, Event No. 25.

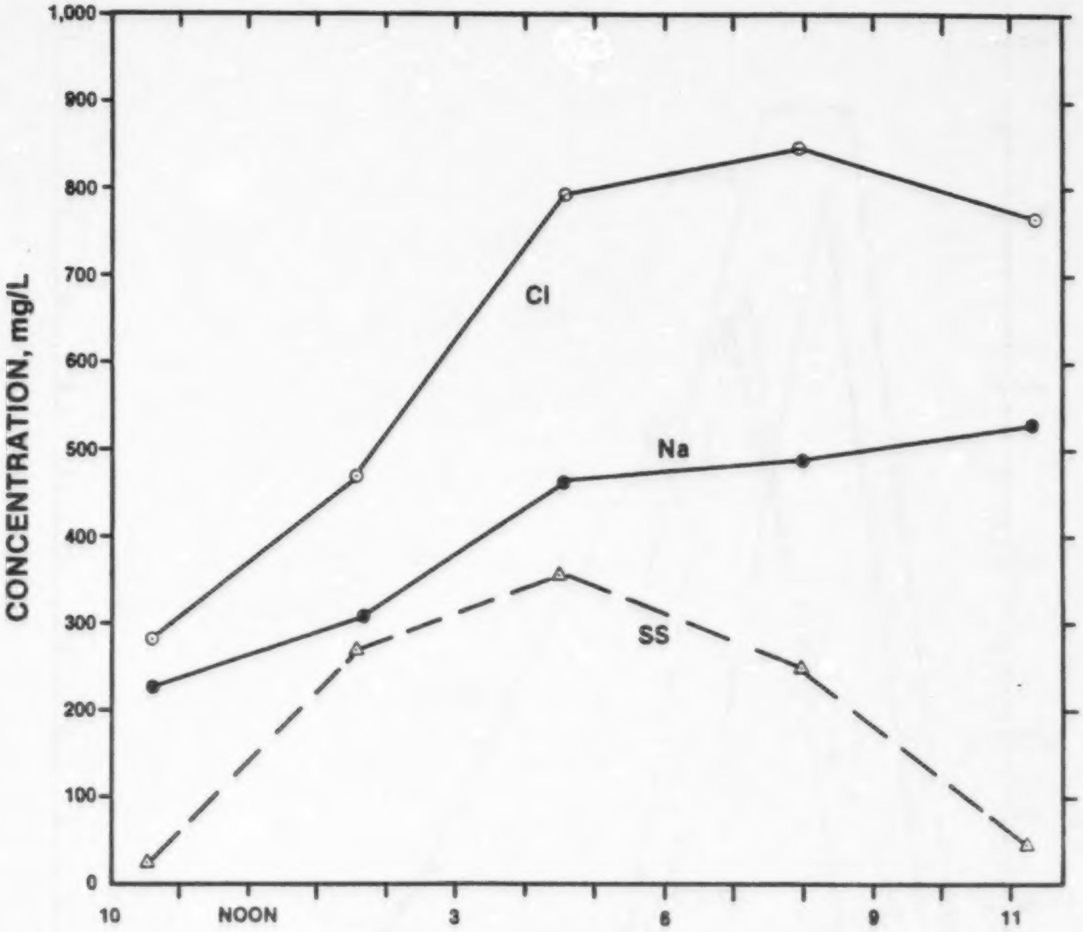

Figure 15. -- Diurnal flux for snowmelt runoff, Station 6, Event No. 24.

low flow event

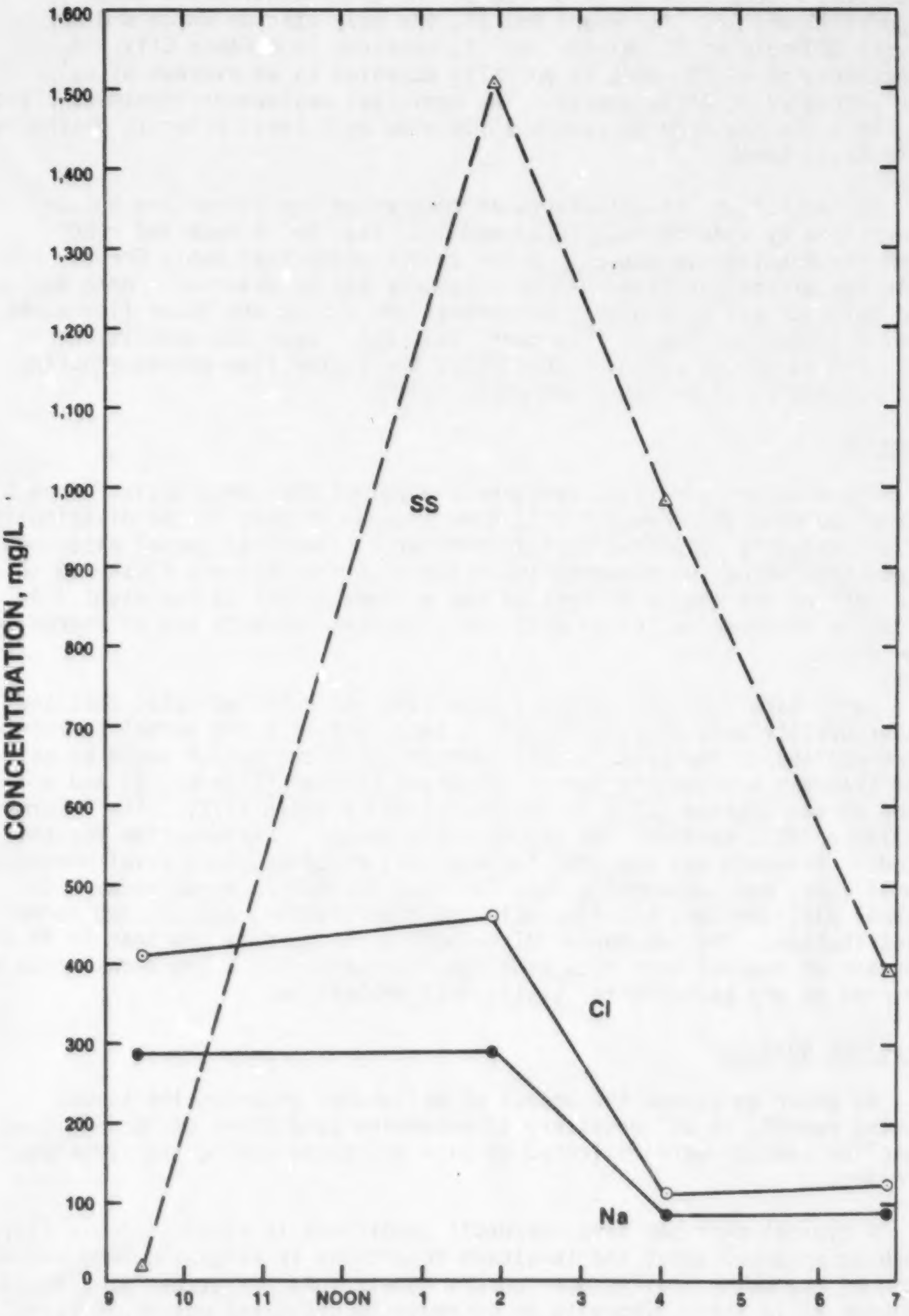

Figure 16. -- Diurnal flux for snowmelt runoff,
Station 6, Event No. 25.

Snowmelt runoff events can result in gross contamination of the receiving watercourse as evidenced by the SS concentrations shown in Figures 13 and 14. For event No. 25, the only station which did not exceed 200 mg/L of SS was Sta. No. 1, upstream from Rapid City. A concentration of 200 mg/L is normally accepted as an average SS value for untreated domestic sewage. The municipal wastewater treatment plant is currently required to remove SS to a 30 mg/L level prior to discharge into Rapid Creek.

Concentrations of pollutants as they enter the stream are better understood by viewing Figures 15 and 16. Sta. No. 6 received runoff from the Robbinsdale subbasin prior to its entry into Rapid Creek. The dilution effect for dissolved constituents can be observed. Both sodium and chloride had much higher concentrations during the lower flow event (No. 24) than the higher flow event (No. 25). Just the opposite was true for suspended solids. Obviously, the higher flow causes scouring and suspension of sediment and other solids.

Skewness

The skewness statistic measures the extent that data deviate from a normal curve. The skewness will have a value of zero if the distribution is a completely symmetric bell-shaped curve (classical normal distribution). A positive value for skewness indicates that the data are clustered to the left of the mean with most of the extreme values to the right. A negative skewness indicates just the opposite, the data are clustered to the right.

Early data from the national data base for NURP indicated that the water quality data were positively skewed; and if a log normal transform were applied to the data, a more symmetrical distribution would be obtained. The skewness evaluations for an up-stream station (Site No. 2) and a down stream station (Site No. 5) are given in Table XXIII. The information in Table XXIII confirms the use of a log normal transformation for this study. Skewness was computed for ammonia, chloride, COD, total phosphorus, total lead, and suspended solids for each station in three modes: (1) normal distribution, (2) flow weighted distribution, and (3) log normal distribution. The log normal distribution of the data was best in 98.4 percent of the 126 data sets examined. Consequently a log-normal mode was adopted as the standard for statistical evaluation.

Baseline Quality

In order to assess the impact of pollutants entering the stream during runoff, it was necessary to determine conditions at normal flows. Baseline samples were collected on nine occasions during the three year project.

A typical data set from nonrunoff conditions is shown in Table XXIV. Nothing abnormal about the in-stream conditions is evident. Some degradation of the water quality does occur, however, as the stream progresses through Rapid City. There is an increase in dissolved materials (see Cl, specific conductance, etc.), suspended solids, and organics (see COD and VSS).

TABLE XXIII. -- Evaluation of Skewness for Selected Water Quality Parameters at Stations Two and Five.

Sta./Mode	Skewness Statistic[a]					
	Ammonia	Chloride	COD	Total P	Total Lead	SS
Sta. 2						
Normal Distribution	2.37	0.34	2.52	2.37	0.44	2.51
Flow-Weighted Distribution	3.32	0.41	4.29	2.68	1.24	2.97
Log-normal Distribution	-0.10	-0.26	-0.04	-0.40	-0.34	-0.58
Sta. 5						
Normal Distribution	0.84	-0.29	1.89	2.52	2.55	1.68
Flow-Weighted Distribution	1.32	0.56	2.18	2.42	2.85	1.68
Log-normal Distribution	-0.34	0.04	-0.06	1.19	-0.37	0.82

[a] Skewness = $\frac{\sum_{i}^{n} = 1 \quad (X_i - \bar{X})/S^{3}}{n-1}$

TABLE XXIV. -- Baseline Data for April 29, 1981

Parameter	Station Number 1	2	3	4	5	6
Alk., mg/L $CaCO_3$ Bicarbonate	-	-	-	-	-	266
Ammonia, mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	0.28
5 day BOD, mg/L	-	-	-	-	-	2
Ult. BOD, mg/L	-	-	-	-	-	3
Total Ca, mg/L	-	-	-	-	-	230
COD, mg/L	<5	6	6	7	7	32
Chloride, mg/L	2.1	3.5	4.4	6.0	7.6	82.4
Diss. Solids, mg/L	-	-	-	-	-	2420
Fecal Coliform, No./100 ml	20*	<5*	20*	60*	280	5500
TKN, mg/L	0.15	0.21	0.28	0.26	0.27	1.0
Diss. TKN, mg/L	-	-	-	-	-	0.81
Total Lead, μg/L	<10	<10	<10	<10	<10	<10
Total Mg, mg/L	-	-	-	-	-	142
Diss. NO_3-NO_2, mg/L N	0.03	0.03	0.01	0.01	0.02	0.18
Oil & Grease, mg/L	-	-	-	-	-	1
pH	8.62	8.81	8.66	8.28	8.46	7.89
Total P, mg/L	<0.01	0.02	0.02	0.03	0.03	0.07
Diss. P, mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Totak K, mg/L	-	-	-	-	-	13.7
Total Na, mg/L	4.3	5.1	5.6	6.1	7.8	140
Spec. Cond., (μmhos/cm)	371	381	452	475	544	2680
Sulfate, mg/L	-	-	-	-	-	1330
SS, mg/L	<4	<4	6	8	12	20
Total Residue, mg/L	246	260	336	342	388	2510
Turbidity, NTU	4.3	1.6	1.9	3.0	3.8	12
VSS, mg/L	<4	<4	<4	<4	4	5

*Fecal coliform colony count was not in the optimum range.

Flow in Rapid Creek at this time was about 20 to 25 cfs. The fecal coliform value is higher at Sta. No. 5 than the acceptable water quality criteria (200/100 ml), but it was not unusual to obtain fecal coliform numbers of this magnitude during baseline sampling at the downstream stations.

A statistical summary from baseline samples for several parameters is given in Table XXV. Most of the data shows that the normal water quality of Rapid Creek is excellent. The data from Sta. No. 4 was affected by a sewer construction project which temporarily leaked sanitary sewage into the stream. The construction was in progress when sample set 3B, July 9, 1980 was obtained. The only results which seemed to vary from the norm were the fecal coliform values which rose to 90,000/100 ml, the maximum baseline concentration. Of course, this also biased the mean and standard deviation shown in Table XXV. These data were not discarded because construction activities are a normal part of urban living, and periodic effects will occur on the stream from construction.

Discrete Samples

Although the routine sampling program resulted in a composite sample for each station, some discrete sampling throughout the hydrograph was also done. Testing for all the normal parameters was done for event No. 10 at Sta. No. 6. A modified list of tests were conducted on all samples collected during event No. 19 at Sta. No. 3, 5, and 6.

Figure 17 illustrates in-stream responses to flow at Sta. No. 3 and 5 for suspended solids, total phosphorus, and specific conductance. Both dissolved and suspended materials appear to vary with changes in runoff. Not much change in flow was recorded at Sta. No. 3, and only minor variations in the parameters mentioned above was detected. At Sta. 5, however, the pronounced hydrograph results in a response for each constituent. Those parameters associated with solids (suspended solids and total phosphorus) increased when the flow increased, while dissolved solids (specific conductance) decrease reflecting a dilution effect from the runoff water.

Figures 18 and 19 show variations in concentrations for selected parameters at Sta. No. 6 for events No. 10 and 19. The higher flows are responsible for a sizable amount of material being scoured from the watershed. At the peak discharge for event No. 10, more than one ton of suspended material was being discharged to Rapid Creek each minute (see Figure 20). Those parameters which are associated with suspended material such as COD, SS, and total phosphorus; very closely follow the hydrographs. This is especially apparent on event No. 10 where the hydrograph had a double peak.

It is clear that the highest sediment loads occur at the higher discharges. Some investigators feel that this is a function of discharge alone while others content that a "first flush" action occurs. The "first flush" concept visualizes loose material, which was deposited on a watershed between runoff events, being washed away with the initial flow during runoff. Thus, the higher solids loading at the start of the

TABLE XXV. -- Statistical Summary of Selected Parameters during Normal Flows

Baseline conditions

Parameter	Station No. 1	2	3	4	5	6
Ammonia, mg/L						
mean	0.02	0.02	0.02	0.02	0.02	0.62
min.	0.01	0.01	0.02	0.01	0.01	0.28
max.	0.04	0.03	0.02	0.06	0.03	1.10
st'd. dev.	0.01	0.01	0	0.02	0.01	0.26
COD, mg/L						
mean	3	5	4	5	5	22
min.	2	2	2	2	2	16
max.	8	10	8	9	8	32
st'd. dev.	2	3	2	3	2	5
Cl, mg/L						
mean	2.6	3.6	4.2	5.1	6.5	82
min.	1.3	2.0	2.1	2.7	3.3	64
max.	3.8	5.0	5.8	6.8	9.1	132
st'd dev.	0.7	0.9	1.1	1.3	2.0	23
Fecal Coliforms, No./100 ml						
mean	53	67	101	11,480	288	149,000
min.	3	3	8	60	35	1,900
max.	190	160	200	90,000	690	1,020,000
st'd. dev.	61	66	78	31,700	207	384,000
TKN, mg/L						
mean	0.07	0.07	0.12	0.15	0.18	1.06
min.	0.03	0.03	0.03	0.03	0.06	0.71
max.	0.15	0.21	0.28	0.26	0.37	1.40
st'd. dev.	0.05	0.07	0.10	0.09	0.12	0.25
pH, units						
mean	8.25	8.50	8.47	8.56	8.36	7.57
min.	7.61	8.26	8.04	8.27	7.74	7.21
max.	8.70	8.81	8.72	8.93	8.60	7.89
st'd. dev.	0.34	0.18	0.23	0.24	0.26	0.23

TABLE XXV. -- Continued

Parameter	Station No. 1	2	3	4	5	6
Total P, mg/L						
mean	0.01	0.02	0.02	0.02	0.02	0.15
min.	<0.01	<0.01	0.01	<0.01	0.01	0.02
max.	0.02	0.03	0.04	0.04	0.04	0.92
st'd. dev.	0.01	0.01	0.01	0.01	0.01	0.31
Total Na, mg/L						
mean	3.7	4.5	4.9	5.6	7.1	130
min.	3.2	3.6	3.9	4.2	5.0	104
max.	4.3	5.6	6.1	6.5	9.0	174
st'd. dev.	0.5	0.8	0.9	0.9	1.4	25
SS, mg/L						
mean	4	6	8	18	13	14
min.	2	2	2	2	6	4
max.	13	14	14	91	32	28
st'd. dev.	4	5	5	28	9	7
VSS, mg/L						
mean	3	2	2	4	3	3
min.	2	2	2	2	2	2
max.	12	5	5	9	9	5
st'd. dev.	4	1	1	3	2	2
Tot. Res., mg/L						
mean	230	253	320	348	369	2,430
min.	202	215	247	266	288	2,080
max.	248	286	385	460	444	3,010
st'd. dev.	14	25	46	65	62	269

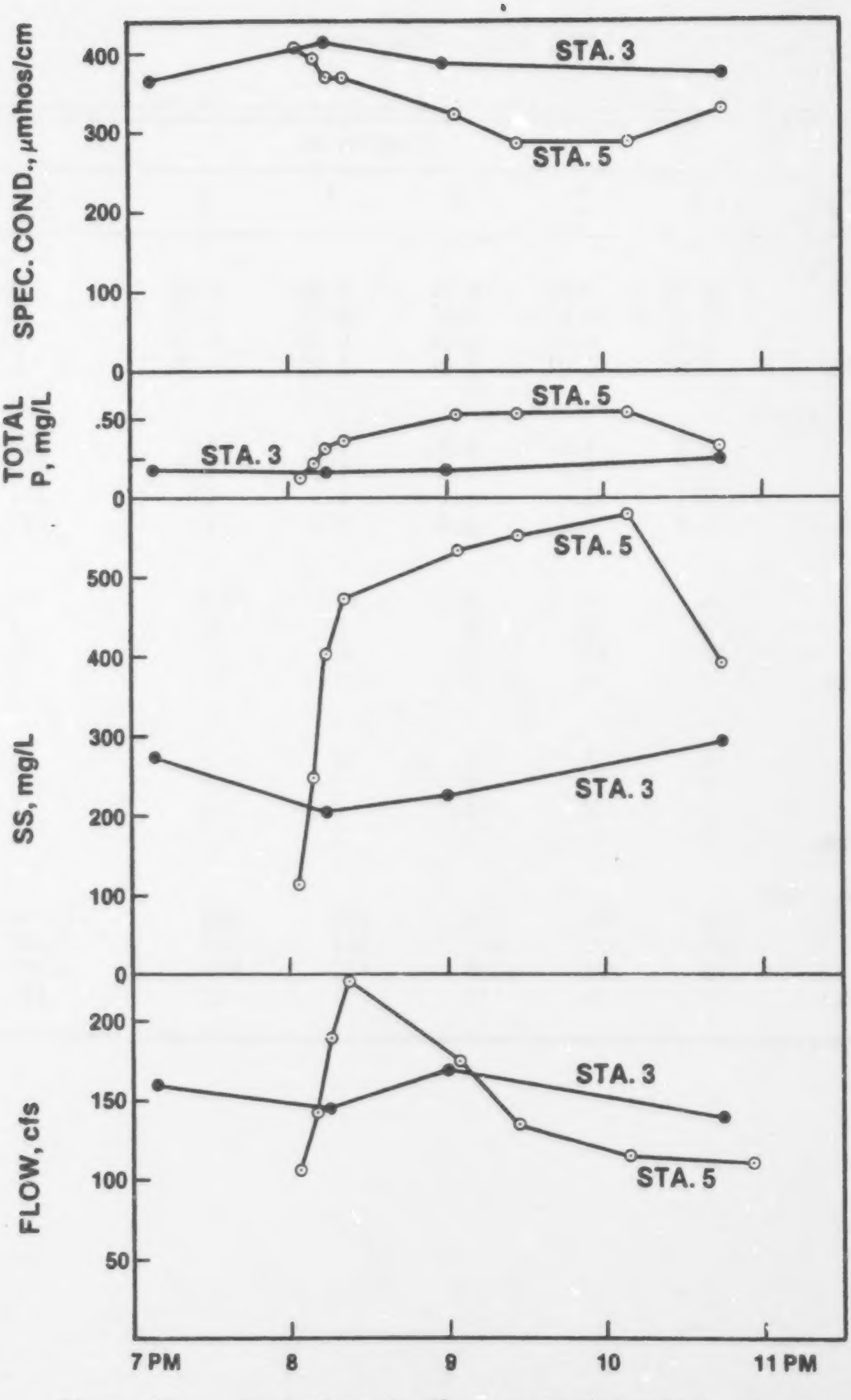

Figure 17. -- Variations in flow, suspended solids, phosphorus and specific conductance for rainfall runoff Event No. 19.

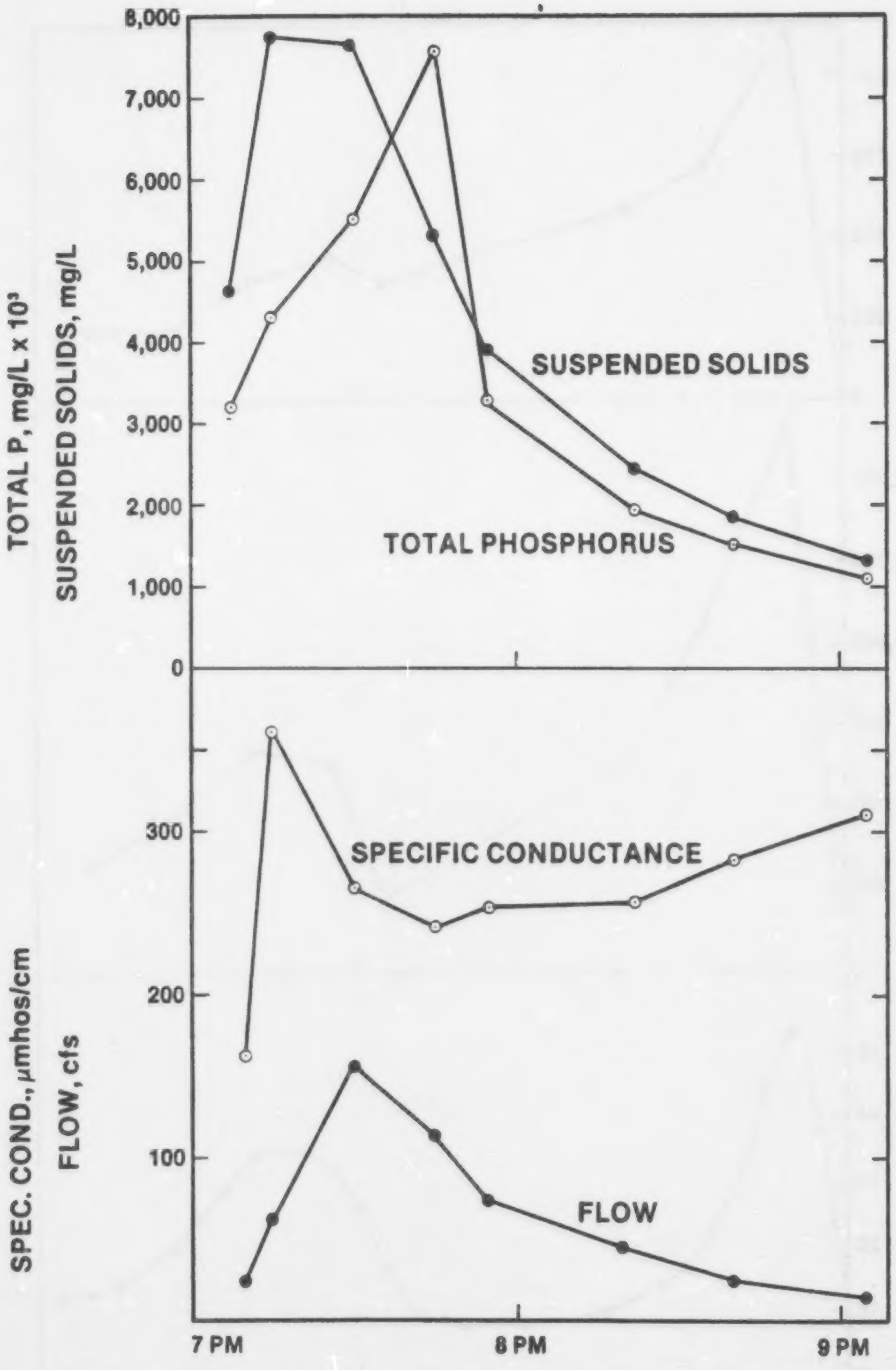

Figure 18. -- Variations in flow, suspended solids, phosphorus, and specific conductance at Station No. 6 for rainfall runoff Event No. 19.

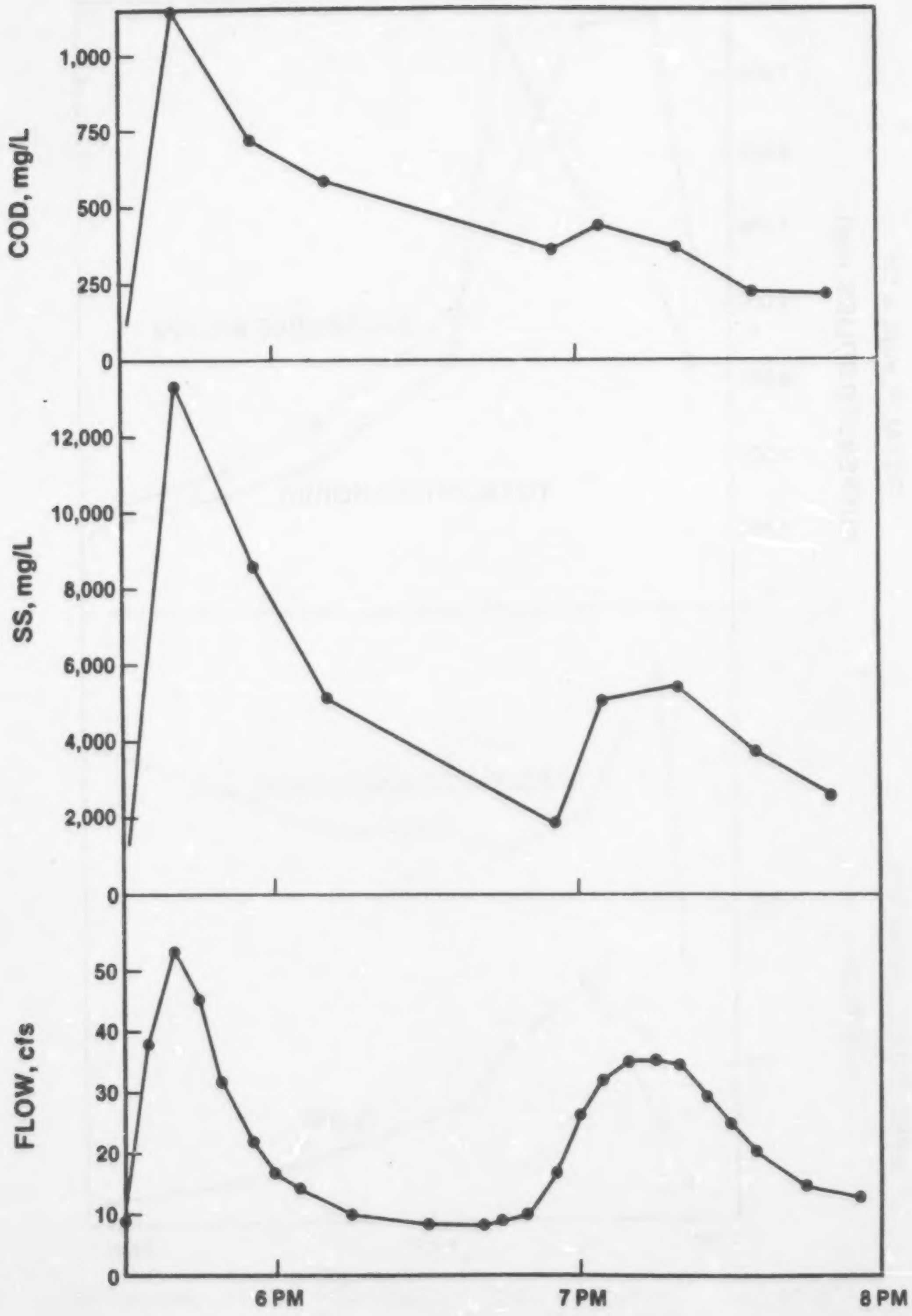

Figure 19. -- Variations in flow, suspended solids, and COD at Station No. 6 for rainfall Event No. 10.

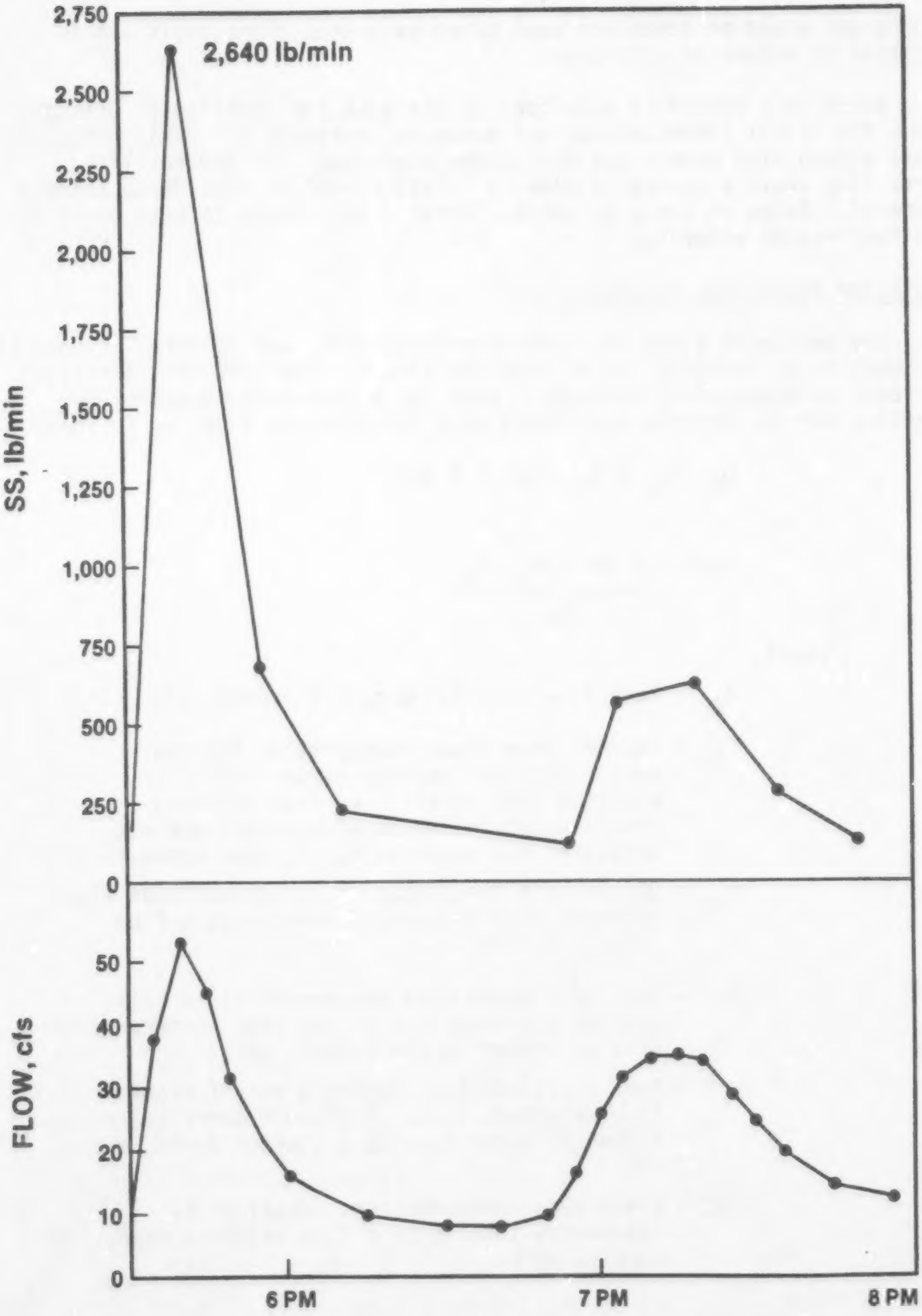

Figure 20. -- Sediment loading rate at Station No. 6, Event No. 10.

hydrograph would be dependent upon other watershed characteristics in addition to volume of discharge.

Based on a procedure developed by the USGS and modified by Grizzard (35), the "first flush" concept was examined in Figure 21. This procedure plots accumulated runoff against accumulated load. If the resulting curve lies above a 45 degree line, a "first flush" is considered to have happened. Based on these criteria, "first flush" seems to take place on the Robbinsdale watershed.

Undiluted Event Mean Concentrations

The undiluted event mean concentration, UEMC, was selected to indicate the quality of runoff which entered the stream. The UEMC was calculated for each parameter from laboratory data for a particular event by subtracting out the portion associated with the baseline flow, as follows:

$$Q_{BL}\ C_{BL} + Q_{RO}\ \text{UEMC} = \overline{Q}\ \text{EMC}$$

and,

$$\text{UEMC} = \frac{\overline{Q}\ \text{EMC} - Q_{BL}\cdot C_{BL}}{Q_{RO}}$$

where,

Q_{BL} = Base flow preceeding runoff events, cfs

C_{BL} = Assumed base flow concentration for the parameter under consideration. Value is assigned from baseline quality obtained from samples collected when runoff was not affecting the quality, mg/L. (See Appendix C.)

Q_{RO} = Mean runoff flow, equal to in-stream mean flow recorded during a runoff event - base flow $(\overline{Q} - Q_{BL})$, cfs.

UEMC = Undiluted event mean concentration, a calculated approximation of the mean concentration of a parameter in the runoff, mg/L.

$\overline{Q}$ = Mean in-stream flow during a runoff event, flow weighted; i.e., $(\overline{Q})$(Runoff duration) = Volume of water passing a station during event, cfs.

EMC = Event mean concentration. Obtained by laboratory testing of a flow weighted composite sample, mg/L.

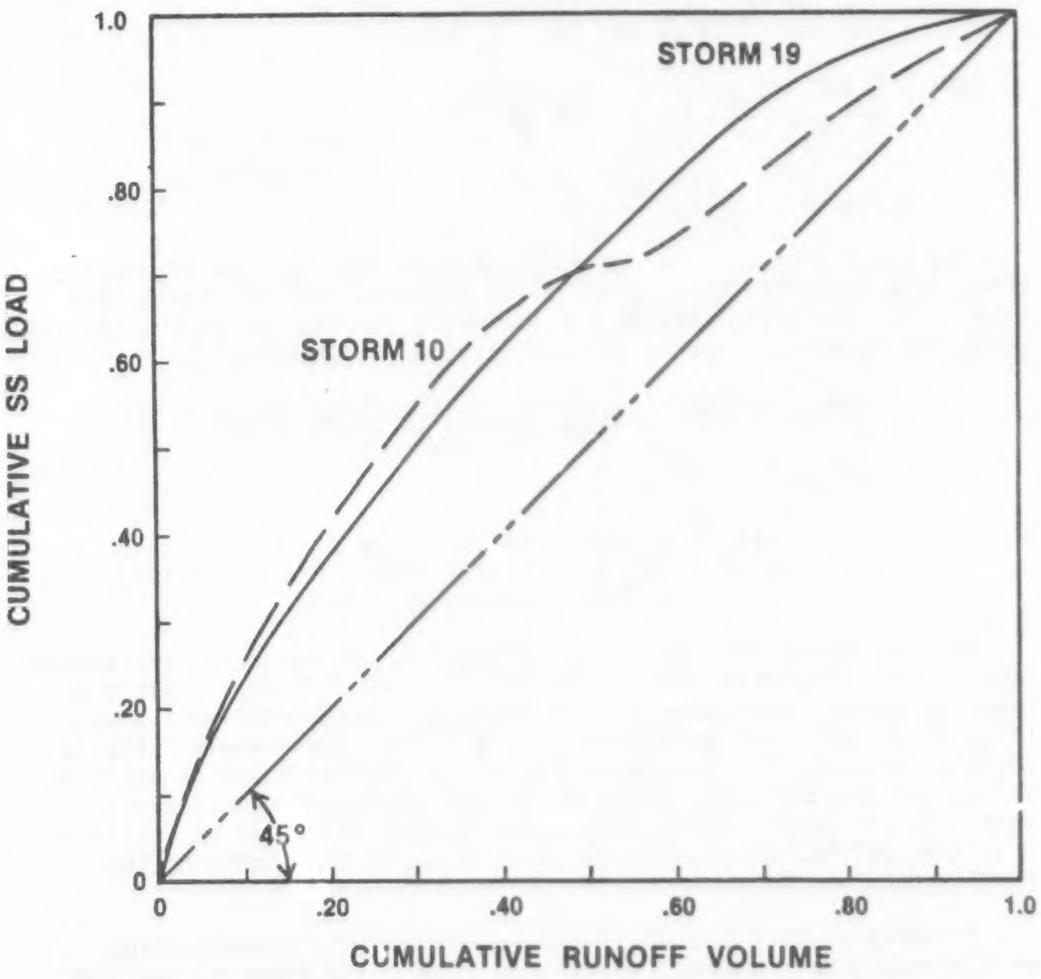

Figure 21. -- Pollutant removal curves for Station No. 6.

A simple example may best illustrate the UEMC:

Given: Station No. 3
Runoff Event No. 5
Base flow = Q_{BL} = 86 cfs
Mean in-stream flow = $\overline{Q}$ = 110 cfs
Instream suspended solids = EMC = 60 mg/L
Base flow suspended solids = C_{BL} = 8 mg/L

To Find: The concentration of suspended solids in the runoff above Sta. No. 3, UEMC.

$$\text{UEMC} = \frac{\overline{Q}\ \text{EMC} - Q_{BL}\ C_{BL}}{Q_{RO}} = \frac{(110)60-86(8)}{110-86}$$

$$= 246\ \text{mg/L} \qquad \underline{\text{ans}}.$$

The above procedure is not applicable at Sta. 56 (the theoretical downstream location) because the event duration was not exactly the same at Station 5 and Station 6. The UEMCs for Sta. 56 were calculated using the duration recorded at each station, as shown below:

$$\text{UEMC}_{56} = \frac{|(\text{UEMC})(\text{Vol RO})|_5 + |(\text{UEMC})(\text{Vol RO})|_6}{\text{Vol RO}_5 + \text{Vol RO}_6}$$

where:

UEMC = as described above, mg/L
Vol RO = Volume of runoff (base flow subtracted) at each station, acre-feet.

Because of the inherent error in sampling and measuring procedures. Some of the calculated UEMC values for Stations 1 through 5 yield a negative value. Obviously this is impossible as a negative 3.5 mg/L of chloride could not be present in the runoff, for example. Statistically, however, these negative values are just as valid as positive values and they were not discarded during subsequent calculations. Generally the reader should view negative UEMC values as an indicator that that particular constituent is very low in the runoff of the event under consideration.

Frequently, only a minor change in the measured concentration or flow would have produced a positive value. For example, the UEMC for Station 1, Storm 1 shows a -21.5 mg/L for a chloride concentration. If the baseflow used in the UEMC calculation was in error by only 3% (a very acceptable field measuring error), the UEMC would calculate to be a positive 14.2 mg/L. Thus, even though some of the UEMC values compute as negative quantities; they appear to give reasonable concentrations. Approximately 3.7% of the UEMC values for Sta. 1 through 5 yield negative concentrations.

TABLE XXVI. -- Log Normal mean values for UEMC, mg/L

Sta. No.	NH_3	COD	Cl^-	TKN	NO_3	Total P	Diss. P	SS	Tot. Res.	VSS
1	0.26	12	5.7	0.56	0.35	0.04	0.01	22	240	3
2	0.12	52	4.8	1.30	0.38	0.25	0.03	289	533	33
3	0.09	91	4.3	1.14	0.35	0.29	0.03	350	552	35
4	0.12	113	5.5	2.42	0.60	0.62	0.06	693	771	81
5	0.11	95	5.8	2.19	0.46	0.55	0.04	595	621	67
56	0.15	119	5.9	2.56	0.51	0.80	0.05	1,038	1,161	104
6	0.18	190	5.5	3.87	0.52	1.48	0.08	2,443	2,786	228

A complete listing of all the UEMC's can be found in Appendix D. A summary is presented in Table XXVI. Although mean values can be misleading statistics, the data clearly show an increase above normal runoff in the stream (Sta. No. 1) as urban runoff enters Rapid Creek. When values from Sta. No. 5 are compared with the theoretical concentrations downstream at Sta. No. 56, the impact of the pollutants from the Robbinsdale watershed are very apparent. Correcting the pollution from this single drainage basin would appear to be a first priority in any subsequent urban runoff controls to be implemented.

Runoff Loads

Rainfall runoff loads for each event were calculated by using the UEMC for each parameter. The UEMC was multiplied by the volume of runoff to give the toal load to the stream in pounds. A complete listing of these loads can be found in Appendix E and a summary is presented in Table XXVII.

Obviously, there is a dramatic increase in material entering Rapid Creek as the stream moves though Rapid City. Table XXVIII shows these increases as a percentage of the load entering Rapid City (at Sta. No. 1). The higher percentages are associated with those constituents which fluctuate with suspended solids, the most predominate being total lead. As previously discussed, lead was almost entirely tied to particulates. Very little dissolved lead was detected.

The magnitudes of some of these loads are staggering. Another

TABLE XXVII. -- Summary of Rainfall Runoff Loads

Parameter	Station No.						
	1	2	3	4	5	6	56
Ammonia, lb							
median	3	9	10	15	18	5	19
min.	<1	2	1	1	1	-1	2
max.	26	108	219	188	193	53	246
COD, lb							
median	64	2,462	5,481	10,660	10,342	5,110	15,601
min.	3	72	441	1,259	441	1,040	1,482
max.	10,457	17,069	32,898	74,770	78,421	41,126	119,546
Cl^-, lb							
median	5	82	179	359	517	122	646
min.	-170	-149	-298	-201	-490	27	-418
max.	1,494	3,368	1,632	5,049	4,332	1,129	5,235
TKN, lb							
median	10	42	46	273	116	98	253
min.	-4	0	8	43	50	25	74
max.	83	728	986	1,766	3,064	1,601	4,665
Total Lead, lb							
median	0.04	2.29	1.31	15.10	5.51	4.94	41.53
min.	0.01	0.03	0.11	1.48	0.21	0.97	4.76
max.	0.91	13.74	14.53	92.34	93.29	72.92	150.54
$NO_3 + NO_2$, lb							
median	4	11	16	66	35	14	92
min.	-4	-1	-6	11	2	2	6
max.	14	125	255	491	694	105	714

TABLE XXVII. -- Continued

Parameter	Station No. 1	2	3	4	5	6	56
Total P, lb							
median	1	12	11	60	52	35	140
min.	1	1	1	7	5	2	16
max.	27	245	344	721	770	864	1,634
Dis. P, lb							
median	1	2	1	4	6	2	8
min.	1	1	1	1	1	1	1
max.	5	41	27	90	49	16	62
Na, lb							
median	13	55	109	484	479	154	778
min.	-24	-120	-177	-168	-340	-4	-219
max.	603	1,158	2,601	4,526	5,208	1,401	6,609
SS, lb							
median	323	7,940	8,292	48,513	46,026	61,646	205,131
min.	2	49	1,089	5,850	5,583	6,245	26,722
max.	5,551	331,258	490,313	762,514	920,668	911,087	1,831,755
VSS, lb							
median	15	1,281	1,181	4,920	5,955	5,259	9,214
min.	2	13	44	891	929	1,046	3,014
max.	425	26,702	55,032	77,658	99,281	70,401	169,681
Tot. Res., lb							
median	2,097	15,315	12,510	59,705	42,821	71,879	99,119
min.	-2,232	447	-5,076	682	-7,814	7,550	26,333
max.	34,657	434,391	676,288	956,119	1,162,452	1,108,618	2,271,070

TABLE XXVIII. -- Percent Increase in Median Runoff Loads Across Rapid City

Parameter	Percent Increase Sta. 1 to Sta. 56
Ammonia	633
COD	24,400
Chloride	12,900
Total Kjeldahl N	2,530
Total Lead	104,000
Nitrate + Nitrite	2,300
Total P	14,000
Dissolved P	800
Sodium	5,980
Suspended Solids	63,500
Volatile Suspended Solids	61,400
Total Residue	4,730

important consideration is that these loads are deposited in the stream within a relatively short time-frame. Downstream from the Rapid City urban area is the municipal wastewater treatment facility. Assuming that the facility treats its sewage to normal levels, Table XXVIX gives an indication of the time required for the effluent to deposit loads corresponding to the runoff loads for a limited number of parameters. The predominant problem is consistently suspended matter and those constituents affiliated with suspended material. Organics, based upon COD, and nutrients would not appear to cause excessive degradation of Rapid Creek based upon acceptable loading rates at the wastewater treatment plant. However, the suspended solids load can be extreme. It would take three months for the treatment plant to discharge the same amount of solids that a moderate storm event would cause to be washed into the creek. It would take almost three years for the effluent to contribute solids equal to those deposited in Rapid Creek in one day by a 2.5 inch rain (Event No. 21).

From the discussion above, it would seem that preventive measures should be directed primarily toward reducing the suspended solids loads. Any suspended solids reduction could also be expected to reduce COD, TKN, lead, phosphorus, VSS, and total residue loadings.

TABLE XXIX. -- Days Needed for Effluent from Wastewater Treatment Facility to Match Urban Runoff Load

Parameter	Urban Runoff Load, lb	Time Required to Generate Urban Runoff Load from Effluent, days
COD		
median	15,600	4.5
min.	1,480	0.4
max.	120,000	34.3
SS		
median	205,000	117
min.	26,700	15
max.	1,830,000	1,045
TKN		
median	253	0.2
min.	74	0.06
max.	4,670	4
Total P		
median	140	0.4
min.	16	0.04
max.	1,640	4.7

Note: Calculations based on an average effluent of 7 MGD, COD=60 mg/L, SS=30 mg/L, TKN=20 mg/L, Total P=6 mg/L.

Statistical Summary of UEMC's

A statistical summary of the undiluted event mean concentration (UEMC) is presented for ammonia, chloride, chemical oxygen demand, total lead, total phosphorus, and suspended solids in Tables XXX through XXXV. Because these data are positively skewed, the log mean is the statistic of choice as a measure of central tendency. However, the sole use of the log mean is misleading if the data set contain any negative values because the logarithm of a negative number is undefined. The tables indicate the number of negative values associated with a particular sample set. Negative values were not included when the log mean was determined. For those data sets which do not contain negative values, the log mean should be used as the measure of central tendency. If the data set contains a substantial number of negative values, such as chlorides for Sta. No. 1 (Table XXXI), it is probably more appropriate to use the mean or median value.

From the data presented, it is apparent that the dissolved constituents

TABLE XXX. -- Summary of UEMC for Ammonia

	Station						
Parameter	1	2	3	4	5	6	56
Mean, mg/L	0.60	0.36	0.18	0.23	0.22	0.26	0.22
Log mean, mg/L	0.26	0.12	0.09	0.12	0.11	0.18	0.15
Median, mg/L	0.26	0.19	0.16	0.18	0.13	0.16	0.13
Min., mg/L	-0.11	0.02	0.02	0.02	0.02	-0.02	0.26
Max., mg/L	3.80	1.96	0.78	1.32	0.62	1.00	0.61
No. samples	15	18	19	19	21	20	19
No. negative values	2	0	0	0	0	2	0

TABLE XXXI. -- Summary of UEMC for Chloride

	Station						
Parameter	1	2	3	4	5	6	56
Mean, mg/L	-0.3	4.0	3.3	5.1	5.7	6.7	5.8
Log mean, mg/L	5.7	4.8	4.3	5.5	5.8	5.5	5.9
Median, mg/L	1.6	2.9	5.0	5.3	4.5	5.5	5.1
Min., mg/L	-31.8	-8.9	-7.6	-3.2	-13.9	2.1	-8.8
Max., mg/L	31.5	20.5	9.2	11.5	21.2	29.4	22.0
No. samples	15	18	19	20	21	21	20
No. negative values	7	4	4	2	2	0	2

TABLE XXXII. -- Summary of UEMC for COD

	Station						
Parameter	1	2	3	4	5	6	56
Mean, mg/L	53	69	102	137	112	214	135
Log mean, mg/L	12	52	91	113	95	190	119
Median, mg/L	2.5	50	78	106	85	171	100
Min., mg/L	2.5	11	47	33	21	87	51
Max., mg/L	359	276	251	377	339	599	367
No. samples	15	17	19	18	21	21	20
No. negative values	0	0	0	0	0	0	0

TABLE XXXIII. -- Summary of UEMC for Total Lead

Parameter	Station 1	2	3	4	5	6	56
Mean, µg/L	14	43	40	173	136	412	193
Log mean, µg/L	7	24	26	121	76	263	138
Median, µg/L	5	36	31	94	79	233	118
Min., µg/L	5	5	5	36	5	80	39
Max., µg/L	90	106	101	466	674	2,160	738
No. samples	9	12	12	12	15	19	14
No. negative values	0	0	0	0	0	0	0

TABLE XXXIV. -- Summary of UEMC for Total Phosphorus

Parameter	Station 1	2	3	4	5	6	56
Mean, mg/L	0.11	0.48	0.38	0.80	0.72	2.00	1.02
Log mean, mg/L	0.04	0.25	0.29	0.62	0.55	1.48	0.80
Median, mg/L	0.08	0.21	0.23	0.53	0.46	1.43	0.62
Min., mg/L	0.01	0.02	0.10	0.22	0.24	0.18	0.30
Max., mg/L	0.67	2.18	1.50	3.64	3.12	6.94	3.05
No. samples	15	18	20	19	22	22	21
No. negative values	0	0	0	0	0	0	0

TABLE XXXV. -- Summary of UEMC for SS

Parameter	Station 1	2	3	4	5	6	56
Mean, mg/L	74	657	489	963	769	3,160	1,290
Log mean, mg/L	22	289	350	693	595	2,440	1,040
Median, mg/L	30	217	290	548	462	2,371	860
Min., mg/L	2	7	91	152	249	654	450
Max., mg/L	375	3,705	2,120	3,850	2,390	11,580	4,580
No. samples	15	18	20	20	22	22	21
No. negative values	0	0	0	0	0	0	0

are fairly low and uniform in concentration throughout the reach of the stream studied. For those parameters associated with suspended material, they increase at each downstream station. In other words the concentration of a constituent at Sta. No. 2 is greater than at Sta. No. 1, and the concentration of the same constituent at Sta. 3 is greater than at Sta. 2, etc. The only variation in this pattern sometimes occurs between Sta. No. 4 and Sta. No. 5 where some sedimentation does occur during events with small flows. The magnitude of the Robbinsdale drainage can clearly be seen by observing the log mean values for SS in Table XXXV. The in-stream concentration nearly doubles (1,040 mg/L compared to 595 mg/L) after the Robbinsdale discharge enters Rapid Creek.

Probability Distribution

The parameter chosen to illustrate in-stream distribution was the UEMC. A statistical summary of the UEMC for several selected parameters has already been presented in Tables XXX through XXXV. An alternate approach would be to develop a set of curves which plot concentration against the frequency of occurrence.

An example of curves of this nature is shown in Figure 22. Both lineal and exponential curves were evaluated for the goodness of fit. Using the coefficient of determination as the measure of fit, a straight line was better for data from Sta. No. 6 while exponential curves gave a better fit for the in-stream stations.

Curves such as Figure 22 would be useful for determining a level of treatment to meet an in-stream concentration. They are not necessary for the situation examined in this project. Rapid Creek is designated as a "cold-water permanent fish life propagation water" (4). This designation carries a limit on suspended solids of 30 mg/L with a maximum variation of up to 60 mg/L. The data indicate that this water quality standard is violated every time rainfall runoff enters Rapid Creek.

Regression Analysis

Early on in this study, it was anticipated that the data would be useful as a planning tools. Indeed these data do allow planners to exercise their judgement concerning the volume and quality of the streamflow in Rapid Creek during snowmelt and runoff events. Initially, however, it was thought that rainfall could be directly related to in-stream concentrations for such parameters as suspended solids, COD, phosphorus, and lead. Relationships were to be established which would correlate rainfall with runoff, runoff to streamflow, streamflow to suspended solids concentration, and suspended solids to parameters which are associated with the solids.

Good correlations for these relationships did not come forth from the data as anticipated. For example, a strong relationship between flow and suspended solids was expected. It did not occur. As previously related (see page 71), suspended solids do tend to increase with an increase in flow; but it is not an increase that can be quantified or predicted from a simple empirical relationship.

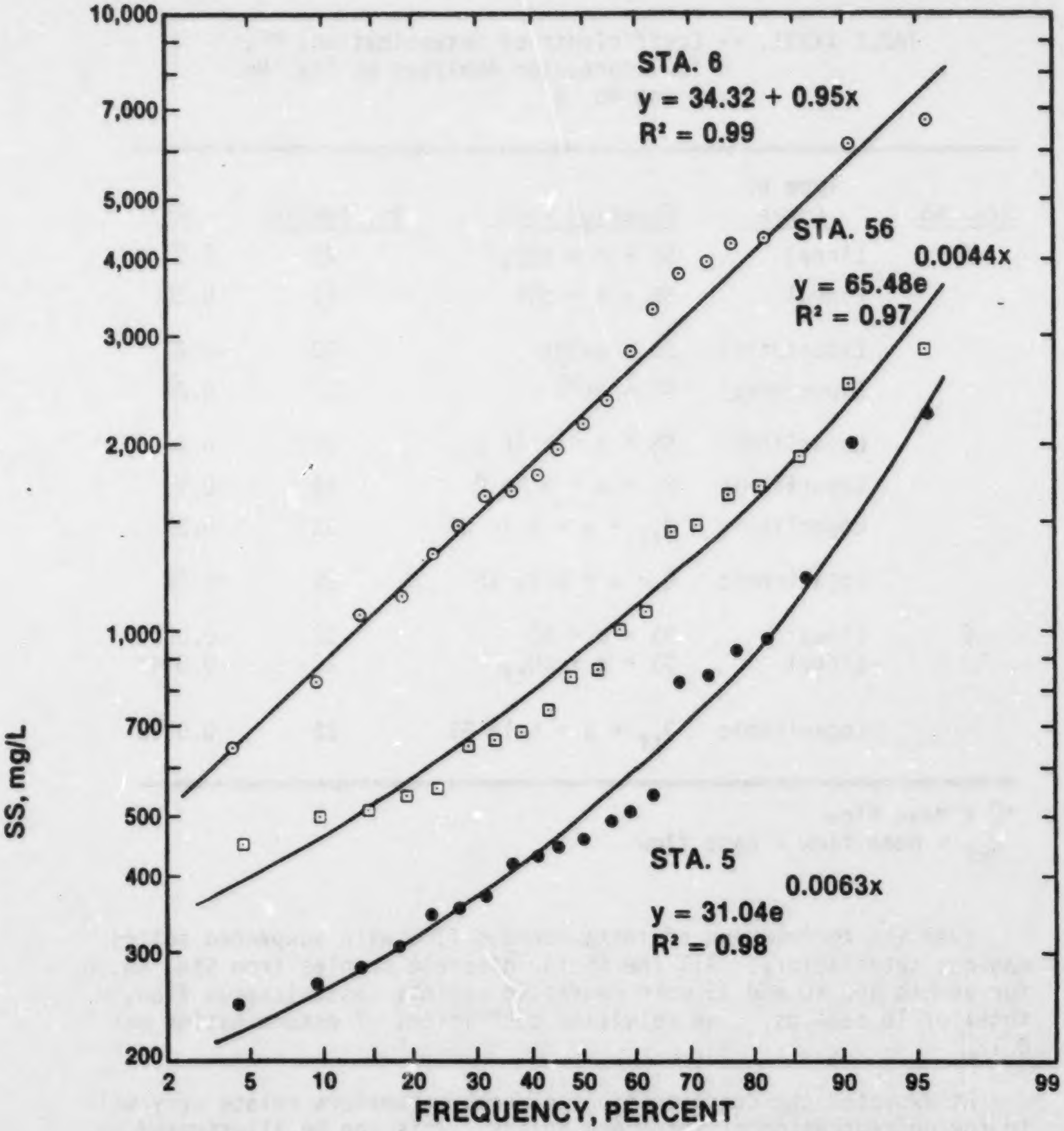

Figure 22. -- Distribution of SS at Station No. 5, 6, and 56 based on UEMC.

A perfect correlation would have a coefficient of determination equal to one. Table XXXVI shows the poor correlation that was achieved at Sta. No. 5 and 6 for SS using the coefficient of determination, R^2, as a measure.

TABLE XXXVI. -- Coefficients of Determination, R^2, for Regression Analyses at Sta. No. 5 and No. 6

Sta. No.	Type of Curve	Equation Form	No. Samples	R^2
5	Lineal	$SS = a + bQ^{*}_{tf}$	22	0.21
	Lineal	$SS = a + b\bar{Q}^{*}$	22	0.20
	Exponential	$SS = ae^{bQ_{tf}}$	22	0.27
	Exponential	$SS = ae^{b\bar{Q}}$	22	0.20
	Logarithmic	$SS = a + b \ln Q_{tf}$	22	0.25
	Logarithmic	$SS = a + b \ln \bar{Q}$	22	0.19
	Logarithmic	$Q_{tf} = a + b \ln SS$	22	0.27
	Logarithmic	$\bar{Q} = a + b \ln SS$	22	0.20
6	Lineal	$SS = a + b\bar{Q}$	22	0.0015
	Lineal	$SS = a + bQ_{tf}$	22	0.0142
	Logarithmic	$Q_{tf} = a + b \ln SS$	22	0.0030

$^{*}\bar{Q}$ = Mean flow
Q_{tf} = Mean flow - Base flow

Even the correlation of instantaneous flow with suspended solids was not satisfactory. All the SS for discrete samples from Sta. No. 6 for events No. 10 and 19 were regressed against instantaneous flow, a total of 16 samples. The resulting coefficient of determination was 0.12.

As expected the concentrations of some parameters relate very well to the concentration of suspended solids. This can be illustrated by examining the correlations between SS and COD, and SS and total phosphorus. Regressions were done with data from each station. Little correlation was found to exist at Sta. No. 1, the background station. Data from all other stations exhibited a high measure of correlation.

Figures 23 and 24 graphically illustrate the lineal relationship which typically existed at Stations 2 through 56. The lineal equations, along with the coefficients of determination, for the computed expressions are given in Table XXXVII. The major anomaly seems to be for SS and COD

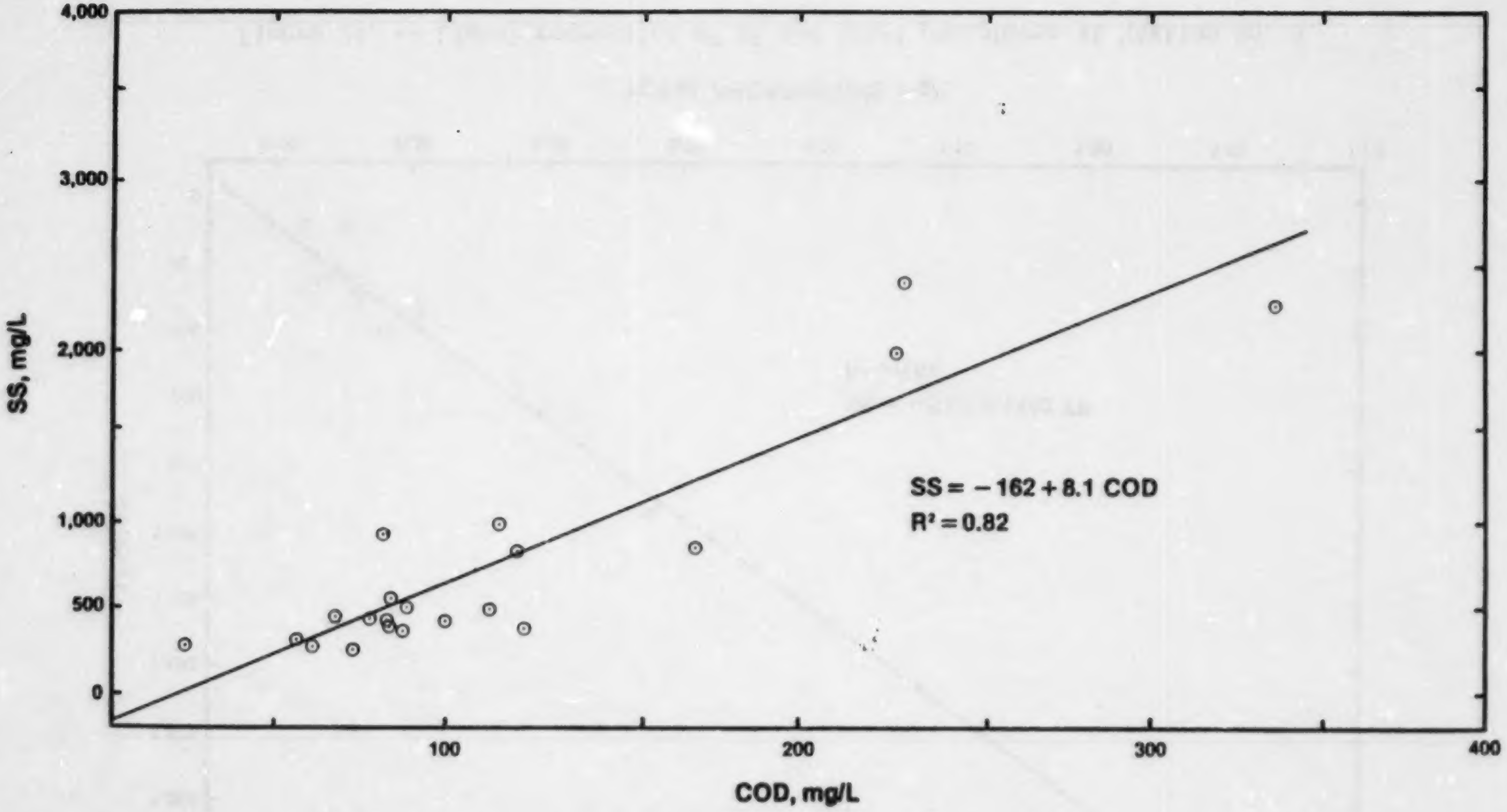

Figure 23. -- Lineal regression of SS and COD at Station No. 5

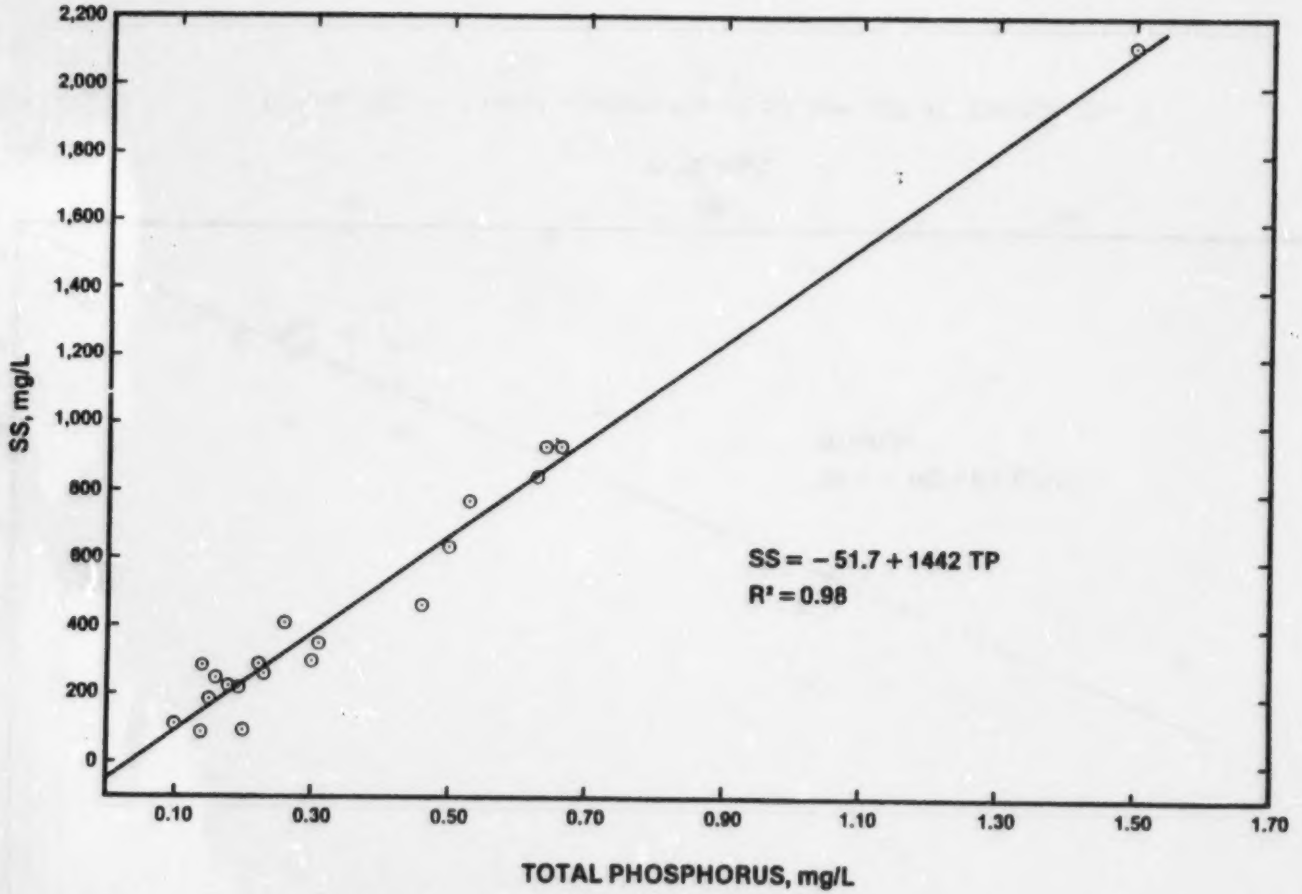

Figure 24. -- Lineal regression of SS and total phosphorus at Station No. 3.

at Sta. 3 where the coefficient of determination was found to only be 0.18. Livestock were sometimes watered in the creek directly above Sta. No. 3. The possible influence of this activity on these data is unknown.

TABLE XXXVII. -- Lineal Correlations of SS with COD and Total Phosphorus

	Total Phosphorus		COD	
Sta. No.	R^2*	Equation	R^2	Equation
2	0.98	SS = -85.1 + 1558 TP**	0.75	SS = -190 + 9.6 COD
3	0.98	SS = -51.7 + 1442 TP	0.18	SS = 100.4 + 3.6 COD
4	0.94	SS = 16.0 + 1155 TP	0.74	SS = -276.1 + 8.4 COD
5	0.88	SS = 144.7 + 866 TP	0.82	SS = -162.1 + 8.1 COD
6	0.81	SS = 245.4 + 1460 TP	0.53	SS = -266.6 + 15.3 COD
56	0.90	SS = 79.8 + 1195 TP	0.65	SS = -186.0 + 10.7 COD

*R^2 = Coefficient of determination
**TP = Total phosphorus
Note: Equations yield concentrations in mg/L

Priority Pollutants

With the exception of asbestos and dioxin, the EPA list of 129 priority pollutants was evaluated three times during the course of this study. Samples were collected in carefully prepared containers, iced and air-freighted to a contract laboratory on the west coast. Unfortunately, very little useful information was received from this exercise.

A full listing of the priority pollutant data is given in Table 17 of Appendix A. Almost all of the information for the metals has been deleted because of unsatisfactory quality control results. Not knowing which information was accurate, the decision was made not to use any of the metals data.

Almost all of the priority pollutant data, metals excepted, were below the analytical detection limits. No concrete evidence of any particular problem was apparent.

One priority pollutant, lead, was routinely tested for at the SDSM&T laboratory. The finished drinking water standard for lead is 50 μg/L. Rapid Creek is a source of drinking water with intakes just below Sta. No. 2 and Sta. No. 5. A statistical summary of in-stream lead concentrations (based on EMCs) is given in Table XXXVIII. Even though the lead standard is exceeded, it is not cause for alarm. All water withdrawn from Rapid Creek is filtered prior to use. The lead in the water is almost entirely associated with particulate matter, as the dissolved lead portion was consistently below detectable limits. Therefore, filtration should provide adequate consumer protection against any toxicity from the high lead concentrations.

TABLE XXXVIII. -- Statistical Summary of In-Stream Total Lead Concentrations

Sta. No.	Log mean, µg/L	Min., µg/L	Max., µg/L
1	5.5	5	14
2	13	5	36
3	13	5	49
4	56	10	280
5	40	5	260
6	268	80	2,000
56	73	24	319

Water Quality Standards

The State of South Dakota has water quality standards, defined according to beneficial use, for every surface water within its geographic boundaries. The beneficial uses for the stretch of Rapid Creek which was studied are listed in Table XXXIX.

TABLE XXXIX. -- Beneficial Uses of Rapid Creek

Domestic Water Supply
Cold Water Permanent Fish Life Propagation
Immersion Recreation
Limited Contact Recreation
Wildlife Propagation and Stock Watering
Irrigation

Table XXXX compares the most stringent criteria for the beneficial uses with the observed in-stream values from this study. As expected, the urban runoff causes the violation of the in-stream water quality standards on a regular basis. Standards for SS, and fecal coliform are exceeded during most runoff events, while the standard for ammonia is exceeded only occasionally. It is difficult to evaluate the significance of these violations. Data which measure the impact of these levels during dynamic, shock loading situations are virtually non-existent.

TABLE XXXX. -- Comparison of Water Quality Criteria and Observed Values

Parameter	Most Stringent Use Criteria	Observed Values In-Stream Min.	Max.	Comment
pH	>6.0 <8.3	6.96	8.98	Violation
Ammonia NH_3-N, mg/l	About 0.3	<0.03	0.67	Violation
Specific Conductance, μmhos/cm	<2,500 @ 25°C	217	1,010	No Problem
Suspended Solids, mg/l	30	2	2,300	Violation
Fecal Coliform, No./100 ml	200	35	68,000	Violation

VI. SUMMARY

Sampling of urban runoff was conducted for three years on five in-stream stations and one major watershed. A theoretical station, No. 56, was used to indicate the in-stream conditions in Rapid Creek below the urban area.

The water quality in Rapid Creek is significantly degraded during urban runoff events. Most of the water quality parameters studied increased in concentration at the downstream locations.

Many variables were recognized as contributing to the water quality changes in Rapid Creek including intensity of rainfall, land use, amount of precipitation, and watershed characteristics. This study did not attempt to partition these variables and readily available relationships to water quality changes were not apparent.

Good estimates of rainfall: runoff responses and the resulting water quality can be made from the data collected. However, it is not possible to quantify the in-stream water quality from precipitation data alone. Even with the quantity of data collected under this project and the site specific hydrologic data obtained, the natural variations in the ecosystem preclude such simplistic predictions on such a complex system. Those interested in water quality should be able to make reasonable predictions of changes in Rapid Creek from urban runoff with the data presented in this report. High correlations of several constituents were obtained when compared to SS. Because the SS test is convenient and expedient, firm estimates of some other loads could be obtained using flow information and the SS test.

The major source of much of the material contributed to Rapid Creek from urban runoff discharges is the Robbinsdale subbasin. This subbasin is the major source of pollutants to Rapid Creek. All other drainages empty into the creek prior to Sta. No. 5. When compared to the urban runoff load in the creek at Sta. No. 5, the Robbinsdale subbasin usually adds another 50 percent or more of the following constituents: COD, TKN, lead, nitrate, phosphorus, SS, VSS, and total solids. In fact, the median SS load to the creek from all urban drainage other than the Robbinsdale subbasin is 46,026 lb.; while the Robbinsdale subbasin alone adds a median SS load of 61,646 lb.

VII. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from this investigation:

1. Urban runoff causes significant water quality degradation of Rapid Creek during runoff events which are a result of rainfall and melting snow.
2. The water quality of Rapid Creek is degraded as it proceeds through the urban area even during normal low-flow conditions when runoff is not a consideration.
3. In-stream water quality standards are not met when wet weather discharges enter Rapid Creek.
4. The major pollutants are sediment and those constituents associated with the sediment load.
5. Based on the limited data gathered in this study, the only significant priority pollutant is lead. Other toxic materials do not appear to be a major problem.
6. It normally takes about 0.15" to 0.20" of precipitation to cause measurable runoff. This amount of rainfall can be expected to occur about 15 times each year.
7. The drainage from the Robbinsdale subbasin is the major source of the urban runoff loading to Rapid Creek.
8. As defined in this report a "first-flush" situation occurs on the Robbinsdale watershed.
9. Water purveyors should exercise caution when securing drinking water from Rapid Creek during wet weather conditions. Known toxics, such as lead, are known to exceed accepted health standards but are currently thought to be removed during water treatment.
10. Firm estimates of COD and total phosphorus concentrations can be obtained from SS values.
11. The runoff/rainfall ratio for the Rapid City urban area ranges from 0.008 to 0.115 with a mean ratio of 0.044.
12. High in-stream concentrations of dissolved constituents, especially sodium and chloride, are evident during snowmelt runoff.
13. The UEMC is an acceptable parameter for measuring the urban runoff load while sampling at a station which receives a base flow.

Recommendations are:

1. The City of Rapid City should find an alternate location for disposal of snow removed from streets. Currently this snow is piled adjacent to Rapid Creek and is an unnecessary source of pollution for the creek.

2. Any attempt to decrease the runoff load to the creek should emphasize the removal of suspended material. Removing suspended solids will also substantially decrease other major pollutants.

3. Remedial measures to reduce the urban runoff load should begin on the Robbinsdale watershed.

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APPENDIX A

Description and Collation of Data
Obtained during the Investigation
of Precipitation Runoff and Its
Effects on Rapid Creek in
Rapid City, South Dakota

(See Separate Volume)

APPENDIX B

Compositing Program
for
Water Quality Sampling

A COMPOSITING PROGRAM FOR WATER QUALITY SAMPLING

BY: Dr. Leland L. Harms, P.E.
South Dakota School of Mines & Technology
Rapid City, South Dakota and
Dr. Herb Smith, Jr., P.E.
Scotchman Industries
Philip, South Dakota

A common problem in environmental engineering is the making of a composite sample which reflects the proper proportion of various discrete water or wastewater samples. A water quality sampling program usually requires that several discrete samples be collected from the water source; possibly a creek, drainage channel, or the wastewater stream at a sewage treatment facility. Normally the discrete samples are brought into the laboratory, and before any analytical work can begin the proper amount of each discrete sample must be extracted and compiled into a single composite sample. The composite sample is to represent the quality of the entire event so fluctuations in the flow at the time of discrete sampling must be evaluated and included in the calculations.

The computer program discussed here eliminates the tedious and error-prone methods of determining the correct aliquots for the composite sample. It is accurate and expeditious. Because of chemical and biological degradation of water quality samples, several of the analytical tests have a limit on the holding time prior to analysis. To meet this deadline, it is common practice to use simplified or short-cut measures when calculating the aliquots. Because water quality data are only as good as the samples used during the laboratory testing program, the use of the computer program has allowed more reliable data to be obtained from the water quality survey.

A complete listing of the program is shown under the heading of COMP4. It is designed to accept up to 100 data points on the hydrograph. Time is entered in military hours (0000 to 2400) thus allowing an automatic indexing feature to compensate for midnight. Input data are time, flow, sample numbers, empty container weights, and container weights after sampling.

To run the program, the user answers to the prompting of the program by entering the total number of data points. The computer will respond by asking for a "time, flowrate and code." The time is entered in military hours, the flowrate in cubic feet per second, and the code is the discrete sample identifying number. If a sample was not collected at the particular time in question, a code of zero is used. If a sample was collected, the computer will ask for the full and empty bottle weights. These data are entered in kilograms.

After all the data have been entered, a table of the data is printed allowing the user to check the input. The program asks the user if the data are correct. If incorrect data have been entered, the user should indicate the data are not satisfactory and enter 'N'. The computer asks for the location of the incorrect information, which can then be corrected. After the user is satisfied that the information is correct, he then enters the desired composite sample volume in liters and the final volume computations are made.

Figure 1 shows a hydrograph from an urban watershed from which four discrete samples were collected at 0850, 0920, 0950, and 1020. Eleven flow measurements were taken. The accompanying print out shows the data entry and computer responses for a 5.0 liter composite sample. The program is designed for the answers to be as percentages of the total discrete sample volume. If the actual volume to be used is desired, simply multiply the sample weight by the percentage.

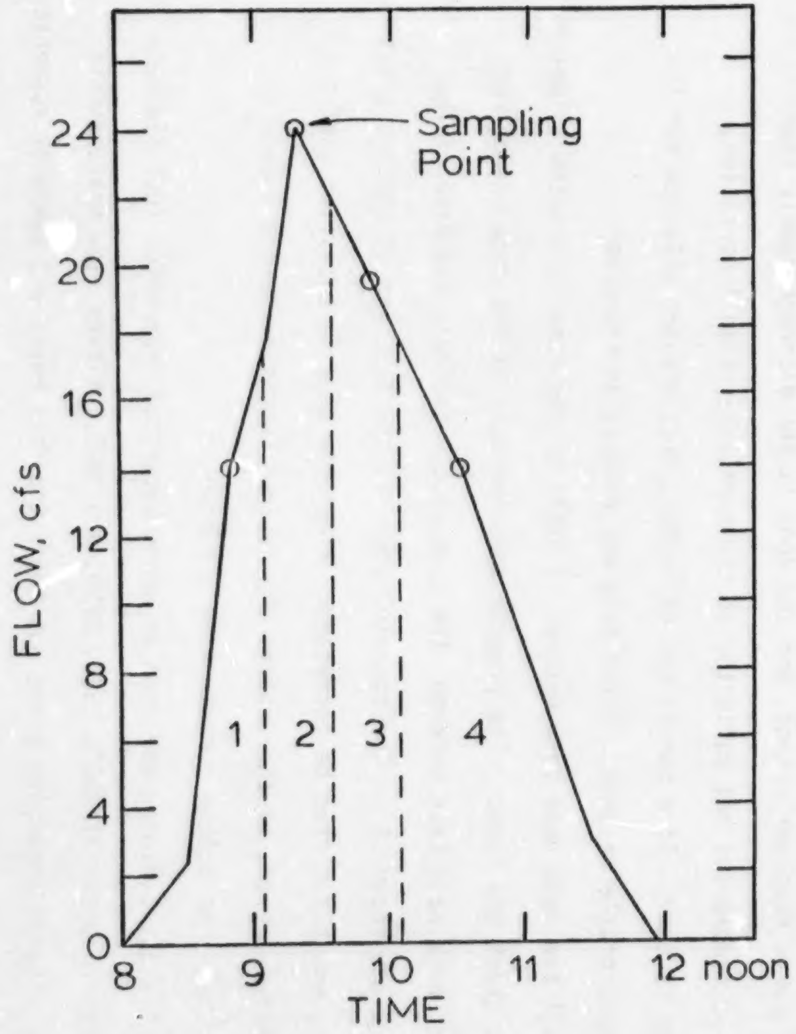

Fig. 1 Storm 12, Sta. 6

```
00640+3X,'NO.',27X,'RATE',15X,'BOTTLE',4X,'BOTTLE',4X,'WEIGHT',/,
00650+52X,'WEIGHT',4X,'WEIGHT')
00660 DO 35 I=1,NP
00670 IF((CODE(I)-0.5).LT.0.0) THEN
00680 WRITE(6,32) I,ITIME(I),XCORD(I),YCORD(I),CODE(I)
00690 ELSE
00700 WRITE(6,32) I,ITIME(I),XCORD(I),YCORD(I),CODE(I),FBW(I),BW(I),SAMPWT(I)
00710 ENDIF
00720 32 FORMAT(I5,2X,I10,3F10.2,3F10.4)
00730 35 CONTINUE
00740C
00750C      CORRECT DATA
00760C
00770 IDEL=0
00780 38 WRITE(6,40)
00790 40 FORMAT(///,'IS THE DATA CORRECT?  Y OR N ')
00800 READ(5,*)ANS
00810 AN='Y'
00820 IF(ANS.EQ.AN) THEN
00830 GO TO 50
00840 ELSE
00850 205 WRITE(6,42)
00860 42 FORMAT('WHICH POINT DO YOU WANT TO CORRECT?  USE ZERO TO PRINT DATA')
00870 READ(5,*) J
00875 IF(J-0)28,28,200
00880 200 WRITE(6,43)
00890 43 FORMAT('INPUT TIME, FLOWRATE, AND CODE')
00900 READ(5,*) ITIME(J),YCORD(J),CODE(J)
00910 TIME=(ITIME(J)+IDEL)*0.01
00920 IT=TIME
00930 XCORD(J)=IT+((TIME-IT)*100/60)
00940 IF((CODE(J)-0.5).LT.0.0) THEN
00950 GO TO 205
00960 ELSE
00970 WRITE(6,44)
00980 44 FORMAT('INPUT FULL BOTTLE WEIGHT AND EMPTY BOTTLE WEIGHT')
00990 READ(5,*) FBW(J),BW(J)
01000 SAMPWT(J)=FBW(J)-BW(J)
01005 GO TO 205
01010 ENDIF
01020 ENDIF
01030C
01040C     CALCULATE INTERMEDIATE POINTS
01050C
01060 50 N=0
01070 DO 70 I=1,NP
01080 IF((CODE(I)-0.5).LT.0.0) THEN
01090 GO TO 70
01100 ELSE
01110 IF(I.EQ.NP) GO TO 72
01120 DO 55 JK=I+1,NP
01130 IF((CODE(JK)-0.5).LT.0.0) GO TO 55
01140 GO TO 56
01150 55 CONTINUE
01160 GO TO 70
01170 56 N=N+1
```

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COMP4

```
PROGRAM COMP4(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
DIMENSION XCORD(100),YCORD(100),CODE(100),SAMPWT(100),ITIME(100)
DIMENSION FBW(100),BW(100),X(300),Y(300),IC(300),AREA(50)
DIMENSION XINT(50),YINT(50)
CHARACTER ANS*1,AN*1
C
C     INITIALIZE
C
DO 5 I=1,50
5 SAMPWT(I)=0.0
C
C     INPUT DATA
C
1 WRITE(6,10)
10 FORMAT ('INPUT TOTAL NUMBER OF POINTS ON HYDROGRAPH',/,
+'MAXIMUM NUMBER IS 100')
READ(5,*) NP
IF(NP.GT.100) THEN
WRITE(6,11)
11 FORMAT('NUMBER OF POINTS IS TOO LARGE....TRY AGAIN')
GO TO 1
ENDIF
WRITE(6,15)
15 FORMAT('INPUT HYDROGRAPH POINTS IN ORDER OF ASCENDING TIME',/,
+'TIME, FLOWRATE, POINT CODE',/,
+'POINT CODE = 0   UNSAMPLED POINT',/,
+'           = X.Y   X = STATION ',/,
+'                   Y = POINT SEQUENCE',/,
+' IF POINT IS SAMPLED, BOTTLE WEIGHT INFORMATION WILL BE REQD')
IDEL=0
DO 20 I=1,NP
WRITE(6,18) I
18 FORMAT('POINT',2X,I2,2X,'TIME, FLOWRATE, CODE')
READ(5,*) ITIME(I),YCORD(I),CODE(I)
IF(I.EQ.1) GO TO 17
IF(ITIME(I).LT.ITIME(I-1)) IDEL=IDEL+2400
17 TIME=(ITIME(I)+IDEL)*0.01
IT=TIME
XCORD(I)=IT+((TIME-IT)*100/60)
IF((CODE(I)-0.5).LT.0.0) THEN
GO TO 20
ELSE
WRITE(6,19)
19 FORMAT('INPUT FULL BOTTLE WEIGHT AND EMPTY BOTTLE WEIGHT')
READ(5,*) FBW(I),BW(I)
SAMPWT(I)=FBW(I)-BW(I)
ENDIF
20 CONTINUE
C
C     DATA ECHO
C
28 WRITE(6,30)
30 FORMAT(///,2X,'POINT',6X,'TIME',6X,'TIME',6X,'FLOW',6X,'CODE',6X,
+'FULL',5X,'EMPTY',5X,'SAMPLE',/,
00640+3X,'NO.',27X,'RATE',15X,'BOTTLE',4X,'BOTTLE',4X,'WEIGHT',/,
00650+52X,'WEIGHT',4X,'WEIGHT')
00660 DO 35 I=1,NP
00670 IF((CODE(I)-0.5).LT.0.0) THEN
00680 WRITE(6,32) I,ITIME(I),XCORD(I),YCORD(I),CODE(I)
00690 ELSE
00700 WRITE(6,32) I,ITIME(I),XCORD(I),YCORD(I),CODE(I),FBW(I),BW(I),SAMPWT(I)
00710 ENDIF
00720 32 FORMAT(I5,2X,I10,3F10.2,3F10.4)
00730 35 CONTINUE
00740C
00750C      CORRECT DATA
00760C
00770 IDEL=0
00780 38 WRITE(6,40)
00790 40 FORMAT(///,'IS THE DATA CORRECT?  Y OR N ')
00800 READ(5,*)ANS
00810 AN='Y'
00820 IF(ANS.EQ.AN) THEN
00830 GO TO 50
00840 ELSE
00850 205 WRITE(6,42)
00860 42 FORMAT('WHICH POINT DO YOU WANT TO CORRECT?  USE ZERO TO PRINT DATA')
00870 READ(5,*) J
00875 IF(J-0)28,28,200
00880 200 WRITE(6,43)
00890 43 FORMAT('INPUT TIME, FLOWRATE, AND CODE')
00900 READ(5,*) ITIME(J),YCORD(J),CODE(J)
00910 TIME=(ITIME(J)+IDEL)*0.01
00920 IT=TIME
00930 XCORD(J)=IT+((TIME-IT)*100/60)
00940 IF((CODE(J)-0.5).LT.0.0) THEN
00950 GO TO 205
00960 ELSE
00970 WRITE(6,44)
00980 44 FORMAT('INPUT FULL BOTTLE WEIGHT AND EMPTY BOTTLE WEIGHT')
00990 READ(5,*) FBW(J),BW(J)
01000 SAMPWT(J)=FBW(J)-BW(J)
01005 GO TO 205
01010 ENDIF
01020 ENDIF
01030C
01040C     CALCULATE INTERMEDIATE POINTS
01050C
01060 50 N=0
01070 DO 70 I=1,NP
01080 IF((CODE(I)-0.5).LT.0.0) THEN
01090 GO TO 70
01100 ELSE
01110 IF(I.EQ.NP) GO TO 72
01120 DO 55 JK=I+1,NP
01130 IF((CODE(JK)-0.5).LT.0.0) GO TO 55
01140 GO TO 56
01150 55 CONTINUE
01160 GO TO 70
01170 56 N=N+1
```

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```
02240 95 J1=1
02250 DO 140 I=1,N+1
02270 A1=0.0
02280 127 DO 130 J=J1,K
02290 A1=A1+(Y(J)*X(J+1)-X(J)*Y(J+1))*0.5
02310 IF (IC(J).EQ.1) GO TO 132
02320 130 CONTINUE
02330 132 AREA(I)=A1+(X(J1)*Y(J+1)-X(J+1)*Y(J1))*0.5
02350 J1 = J+1
02360 140 CONTINUE
02370 AT=0.0
02380 DO 145 I=1,N+1
02390 AT=AT+AREA(I)
02400 145 CONTINUE
02410C
02420C     COMPUTE WEIGHT PROPORTIONS
02430C
02440 WRITE(6,150)
02450 150 FORMAT(///,'WHAT IS THE TOTAL VOLUME OF FINAL DESIRED COMPOSITE?')
02460 READ (5, *) WT
02470 WRITE (6, 160)
02480 160 FORMAT(///,1X,'STATION',4X,'SAMPLE',4X,'SAMPLE',5X,'AREA',5X,
02490+'PERCENT',/,
02500+3X,'NO.',7X,'NO.',6X,'WEIGHT',16X,'OF',/,
02510+41X,'DISCRETE')
02520 J=0
02530 TW=0
02540 DO 170 I=1,NP
02550 IF((CODE(I)-0.5).LT.0.0) GO TO 170
02560 J=J+1
02570 PER=((AREA(J)/AT)*WT*100.0)/SAMPWT(I)
02580 TW=TW+PER*SAMPWT(I)/100.0
02590C
02600C     OUTPUT RESULTS
02610C
02620 ISTAT=CODE(I)
02630 WRITE(6,165) ISTAT,CODE(I),SAMPWT(I),AREA(J),PER
02640 165 FORMAT(I5,5X,F5.2,4X,2F10.4,F10.2)
02650 170 CONTINUE
02660 WRITE(6,175) AT
02670 175 FORMAT(///,'TOTAL AREA UNDER HYDROGRAPH IS  ',2X,F10.4)
02680 WRITE(6,130) WT,TW
02690 180 FORMAT('DISCRETE VOLUME CHECK',/,
02700+'VOLUME DESIRED =          ',F10.2,/,
02710+'VOLUME AS CALCULATED = ',F10.2)
02720 WRITE(6,185)
02730 185 FORMAT('DO YOU WANT TO RUN ANOTHER CASE?  Y OR N')
02740 READ(5,*) ANS
02750 IF (ANS.EQ.AN) GO TO 1
02760 CALL EXIT
02770 END
```

```
01180 XINT(N)=(XCORD(I)+XCORD(JK))/2.0
01190 DO 60 J=1,NP
01200 IF(XINT(N).GT.XCORD(J)) GO TO 60
01210 DEL=XINT(N)-XCORD(J-1)
01220 DELY=YCORD(J)-YCORD(J-1)
01230 DELX=XCORD(J)-XCORD(J-1)
01240 YINT(N)=YCORD(J-1)+DELY*DEL/DELX
01270 GO TO 70
01280 60 CONTINUE
01290 ENDIF
01300 70 CONTINUE
01310C
01320C     CHECK INTERMEDIATE POINTS AND MERGE ARRAYS
01330C
01340 72 K=0
01350 IJ=1
01380 DO 90 I=1,N
01390 DO 80 J=IJ,NP
01410 IF(XINT(I).GE.XCORD(J)) THEN
01420 K=K+1
01430 X(K)=XCORD(J)
01440 Y(K)=YCORD(J)
01450 IC(K)=0
01455 GO TO 80
01560 ELSE
01750 K=K+1
01760 X(K)=XINT(I)
01770 Y(K)=YINT(I)
01780 IC(K)=1
01790 K=K+1
01800 X(K)=XINT(I)
01810 Y(K)=0.0
01820 IC(K)=0
01830 K=K+1
01840 X(K)=XINT(I)
01850 Y(K)=YINT(I)
01860 IC(K)=0
01870 IJ=J
01880 ENDIF
01890 74 IF(I.EQ.N) THEN
01910 DO 75 NN=IJ,NP
01920 K=K+1
01930 X(K)=XCORD(NN)
01940 Y(K)=YCORD(NN)
01950 IC(K)=0
01960 75 CONTINUE
01970 IC(K-1)=1
01990 ELSE
02000 GO TO 90
02010 ENDIF
02011 GO TO 95
02030 80 CONTINUE
02040 90 CONTINUE
02120C
02130C     COMPUTE AREAS
02140C
```

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```
02240 95 J1=1
02250 DO 140 I=1,N+1
02270 A1=0.0
02280 127 DO 130 J=J1,K
02290 A1=A1+(Y(J)*X(J+1)-X(J)*Y(J+1))*0.5
02310 IF (IC(J).EQ.1) GO TO 132
02320 130 CONTINUE
02330 132 AREA(I)=A1+(X(J1)*Y(J+1)-X(J+1)*Y(J1))*0.5
02350 J1 = J+1
02360 140 CONTINUE
02370 AT=0.0
02380 DO 145 I=1,N+1
02390 AT=AT+AREA(I)
02400 145 CONTINUE
02410C
02420C     COMPUTE WEIGHT PROPORTIONS
02430C
02440 WRITE(6,150)
02450 150 FORMAT(///,'WHAT IS THE TOTAL VOLUME OF FINAL DESIRED COMPOSITE?')
02460 READ (5, *) WT
02470 WRITE (6, 160)
02480 160 FORMAT(///,1X,'STATION',4X,'SAMPLE',4X,'SAMPLE',5X,'AREA',5X,
02490+'PERCENT',/,
02500+3X,'NO.',7X,'NO.',6X,'WEIGHT',16X,'OF',/,
02510+41X,'DISCRETE')
02520 J=0
02530 TW=0
02540 DO 170 I=1,NP
02550 IF((CODE(I)-0.5).LT.0.0) GO TO 170
02560 J=J+1
02570 PER=((AREA(J)/AT)*WT*100.0)/SAMPWT(I)
02580 TW=TW+PER*SAMPWT(I)/100.0
02590C
02600C     OUTPUT RESULTS
02610C
02620 ISTAT=CODE(I)
02630 WRITE(6,165) ISTAT,CODE(I),SAMPWT(I),AREA(J),PER
02640 165 FORMAT(I5,5X,F5.2,4X,2F10.4,F10.2)
02650 170 CONTINUE
02660 WRITE(6,175) AT
02670 175 FORMAT(///,'TOTAL AREA UNDER HYDROGRAPH IS  ',2X,F10.4)
02680 WRITE(6,130) WT,TW
02690 180 FORMAT('DISCRETE VOLUME CHECK',/,
02700+'VOLUME DESIRED =         ',F10.2,/,
02710+'VOLUME AS CALCULATED = ',F10.2)
02720 WRITE(6,185)
02730 185 FORMAT('DO YOU WANT TO RUN ANOTHER CASE?  Y OR N')
02740 READ(5,*) ANS
02750 IF (ANS.EQ.AN) GO TO 1
02760 CALL EXIT
02770 END
```

COMPUTER PRINT OUT

```
INPUT TOTAL NUMBER OF POINTS ON HYDROGRAPH
MAXIMUM NUMBER IS 100
? 11
INPUT HYDROGRAPH POINTS IN ORDER OF ASCENDING TIME
TIME, FLOWRATE, POINT CODE
POINT CODE = 0   UNSAMPLED POINT
           = X.Y   X = STATION
                   Y = POINT SEQUENCE
 IF POINT IS SAMPLED, BOTTLE WEIGHT INFORMATION WILL BE REQD
POINT   1  TIME, FLOWRATE, CODE
? 0800,0,0
POINT   2  TIME, FLOWRATE, CODE
? 0830,2.4,0
POINT   3  TIME, FLOWRATE, CODE
? 0850,14,6.1
INPUT FULL BOTTLE WEIGHT AND EMPTY BOTTLE WEIGHT
? 2.7600,0.073
POINT   4  TIME, FLOWRATE, CODE
? 0905,17.5,0
POINT   5  TIME, FLOWRATE, CODE
? 0920,24,6.2
INPUT FULL BOTTLE WEIGHT AND EMPTY BOTTLE WEIGHT
? 2.945,0.073
POINT   6  TIME, FLOWRATE, CODE
? 0935,22,0
POINT   7  TIME, FLOWRATE, CODE
? 0950,20,6.3
INPUT FULL BOTTLE WEIGHT AND EMPTY BOTTLE WEIGHT
? 2.994,0.073
POINT   8  TIME, FLOWRATE, CODE
? 1005,17.8,0
POINT   9  TIME, FLOWRATE, CODE
? 1020,14,6.4
INPUT FULL BOTTLE WEIGHT AND EMPTY BOTTLE WEIGHT
? 2.914,0.073
POINT  10  TIME, FLOWRATE, CODE
? 1130,3,0
POINT  11  TIME, FLOWRATE, CODE
? 1200,0,0


  POINT      TIME      TIME      FLOW      CODE      FULL     EMPTY    SAMPLE
   NO.                           RATE               BOTTLE   BOTTLE    WEIGHT
                                                    WEIGHT   WEIGHT
    1         800      8.00      0.00      0.00
    2         830      8.50      2.40      0.00
    3         850      8.83     14.00      6.10     2.7600    .0730    2.6870
    4         905      9.08     17.50      0.00
    5         920      9.33     24.00      6.20     2.9450    .0730    2.8720
    6         935      9.58     22.00      0.00
    7         950      9.83     20.00      6.30     2.9940    .0730    2.9210
    8        1005     10.08     17.80      0.00
    9        1020     10.33     14.00      6.40     2.9140    .0730    2.8410
   10        1130     11.50      3.00      0.00
   11        1200     12.00      0.00      0.00


IS THE DATA CORRECT?  Y OR N
? 'y'
```

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```
WHAT IS THE TOTAL VOLUME OF FINAL DESIRED COMPOSITE?
? 5.0


 STATION    SAMPLE    SAMPLE     AREA     PERCENT
   NO.       NO.      WEIGHT                 OF
                                          DISCRETE
    6       6.10       2.6870    7.2708     31.59
    6       6.20       2.8720   10.9375     44.46
    6       6.30       2.9210    9.9750     39.87
    6       6.40       2.8410   14.6417     60.17


TOTAL AREA UNDER HYDROGRAPH IS        42.8250
DISCRETE VOLUME CHECK
VOLUME DESIRED =              5.00
VOLUME AS CALCULATED =        5.00
DO YOU WANT TO RUN ANOTHER CASE?  Y OR N
? 'n'
```

APPENDIX C

Baseflow Concentrations Assigned to each Runoff Event

TABLE C1. -- Baseflow Concentrations Assigned to Runoff Events at Station 1

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	75.	0.015	2.5	2.5	20	--	0.04
2	26.	0.015	2.5	2.5	20	--	0.04
3	103.	0.015	2.5	1.3	20	0.09	0.04
4	90.	0.015	2.5	1.3	20	0.09	0.04
5	82.	0.015	2.5	1.3	20	0.09	0.04
6	32.	0.015	2.5	2.5	20	0.09	0.04
7	5.6	0.015	2.5	2.5	20	0.09	0.04
8	4.5	--	--	--	--	--	--
9	7.5	--	--	--	--	--	--
10	116.	--	--	--	--	--	--
11	110.	0.015	2.5	2.5	57	0.09	0.04
12	98.	--	--	--	--	--	--
13	50.	--	--	--	--	--	--
14	61.	0.015	2.5	2.5	57	0.09	0.04
15	50.	--	--	--	--	--	--
16	23.	--	--	--	--	--	--
17	92.	0.015	2.5	2.5	57	0.05	0.04
18	127.	0.015	2.5	2.5	57	0.05	0.04
19	75.	--	--	--	--	--	--
20	58.	0.015	2.5	2.5	57	0.05	0.04
21	42.	0.015	2.5	2.5	57	0.05	0.04
22	1.7	--	--	--	--	--	--
26	42.	0.02	2.5	2.5	15	0.025	0.04
28	17.	--	--	--	--	--	--
29	13.	0.02	2.5	2.5	15	0.025	0.02
31	25.	0.02	2.5	2.5	15	0.025	0.01
32	29.	0.02	2.5	2.5	15	0.025	0.01
33	143.	0.02	2.5	2.5	15	0.025	0.01

TABLE C2. -- Baseflow Concentrations Assigned to Runoff Events at Station 2

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	82	0.015	3.6	3.1	21	--	0.05
2	38	0.015	3.6	3.1	21	--	0.05
3	116	0.015	--	2	21	0.08	0.05
4	95	0.015	3.6	2	21	0.08	0.05
5	98	0.015	3.6	2	21	0.08	0.05
6	40	0.015	3.6	3.1	21	0.08	0.05
7	20	0.015	3.6	3.1	21	0.08	0.05
8	18	--	--	--	--	--	--
9	19	--	--	--	--	--	--
10	134	--	--	--	--	--	--
11	127	0.015	5.3	3.6	40	0.08	0.05
12	114	--	--	--	--	--	--
13	64	--	--	--	--	--	--
14	84	0.015	5.3	3.6	40	0.08	0.07
15	72	--	--	--	--	--	--
16	39	--	--	--	--	--	--
17	97	0.015	5.3	3.5	--	0.03	0.05
18	140	0.015	5.3	3.5	--	0.03	0.05
19	68	--	--	--	--	--	--
20	56	0.015	5.3	3.5	40	0.03	0.05
21	38	0.015	5.3	3.5	--	0.03	0.05
22	11	--	--	--	--	--	--
26	53	0.015	3.5	4.2	44	0.08	0.06
28	38	--	--	--	--	--	--
29	27	0.015	3.5	4.2	44	0.08	0.06
31	40	0.015	3.5	4.1	44	0.08	0.04
32	47	0.015	3.5	4.1	44	0.08	0.04
33	155	0.015	3.5	4.1	44	0.08	0.04

TABLE C1. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	8.24	0.005	--	3.2	5	230	0.5	2
2	8.24	0.005	0.005	3.2	2	230	0.5	2
3	8.24	0.005	0.005	3.2	8	202	0.5	2
4	8.24	0.005	0.005	3.2	8	202	0.5	7
5	8.24	0.005	0.005	3.2	5	202	0.5	4
6	8.24	0.005	0.005	3.7	2	230	0.5	2
7	8.24	0.005	0.005	3.7	2	230	0.5	2
8	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--
11	8.24	0.005	0.005	3.7	2	230	1.25	2
12	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--
14	8.24	0.005	0.005	3.7	2	230	1.25	2
15	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--
17	8.24	0.005	0.005	3.5	2	230	1.25	2
18	8.24	0.005	0.005	3.5	2	230	1.25	2
19	--	--	--	--	--	--	--	--
20	8.24	0.005	0.005	3.5	2	230	1.25	2
21	8.24	0.005	0.005	3.5	2	230	1.25	2
22	--	--	--	--	--	--	--	--
26	8.24	0.005	0.005	3.7	2	230	0.68	2
27	--	--	--	--	--	--	--	--
28	--	--	--	--	--	--	--	--
29	8.24	0.005	0.005	3.7	2	230	0.68	2
31	8.03	0.005	0.005	3.7	2	230	0.68	2
32	8.03	0.005	0.005	3.7	2	230	0.68	2
33	8.03	0.005	0.005	3.7	2	230	0.68	2

TABLE C2. -- Baseflow Concentrations Assigned to Runoff Events at Station 2

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	82	0.015	3.6	3.1	21	--	0.05
2	38	0.015	3.6	3.1	21	--	0.05
3	116	0.015	--	2	21	0.08	0.05
4	95	0.015	3.6	2	21	0.08	0.05
5	98	0.015	3.6	2	21	0.08	0.05
6	40	0.015	3.6	3.1	21	0.08	0.05
7	20	0.015	3.6	3.1	21	0.08	0.05
8	18	--	--	--	--	--	--
9	19	--	--	--	--	--	--
10	134	--	--	--	--	--	--
11	127	0.015	5.3	3.6	40	0.08	0.05
12	114	--	--	--	--	--	--
13	64	--	--	--	--	--	--
14	84	0.015	5.3	3.6	40	0.08	0.07
15	72	--	--	--	--	--	--
16	39	--	--	--	--	--	--
17	97	0.015	5.3	3.5	--	0.03	0.05
18	140	0.015	5.3	3.5	--	0.03	0.05
19	68	--	--	--	--	--	--
20	56	0.015	5.3	3.5	40	0.03	0.05
21	38	0.015	5.3	3.5	--	0.03	0.05
22	11	--	--	--	--	--	--
26	53	0.015	3.5	4.2	44	0.08	0.06
28	38	--	--	--	--	--	--
29	27	0.015	3.5	4.2	44	0.08	0.06
31	40	0.015	3.5	4.1	44	0.08	0.04
32	47	0.015	3.5	4.1	44	0.08	0.04
33	155	0.015	3.5	4.1	44	0.08	0.04

TABLE C2. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	8.5	0.02	--	4.	7	225	1.3	3
2	8.5	0.02	0.005	4.	7	225	1.3	3
3	8.5	0.02	0.005	4.	7	225	1.3	3
4	8.5	0.02	0.005	4.	7	225	1.3	3
5	8.5	0.02	0.005	4.	7	225	1.3	3
6	8.5	0.02	0.005	4.	7	225	1.3	3
7	8.5	0.02	0.005	4.	2	225	1.3	3
8	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--
11	8.5	0.02	0.005	4.6	2	244	1.7	2
12	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--
14	8.5	0.02	0.005	5.1	2	268	1.7	3
15	--	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--	--
17	8.5	0.02	0.005	5.1	2	268	1.7	2
18	8.5	0.02	0.005	5.1	2	268	1.7	2
19	--	--	--	--	--	--	--	--
20	8.5	0.02	0.005	5.1	2	268	1.7	2
21	8.5	0.02	0.005	5.1	2	268	1.7	2
22	--	--	--	--	--	--	--	--
26	8.5	0.02	0.005	5.4	4	277	1.8	2
28	--	--	--	--	--	--	--	--
29	8.5	0.02	0.005	5.4	4	277	1.8	2
31	8.37	0.02	0.005	5.4	4	277	1.8	2
32	8.37	0.02	0.005	5.4	4	277	1.8	2
33	8.37	0.02	0.005	5.4	4	277	1.8	2

TABLE C3. -- Baseflow Concentrations Assigned to Runoff Events at Station 3

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	83	0.015	3.6	3.3	79	--	0.065
2	36	0.015	3.6	3.3	79	--	0.065
3	78	0.015	--	2.1	79	0.08	0.065
4	73	0.015	3.6	2.1	79	0.08	0.065
5	86	0.015	3.6	2.1	79	0.08	0.065
6	50	0.015	3.6	3.3	79	0.08	0.065
7	19	0.015	3.6	3.3	79	0.08	0.065
8	23	--	--	--	--	--	--
9	19	--	--	--	--	--	--
10	143	--	--	--	--	--	--
11	143	0.015	4.5	4.4	93	0.17	0.05
12	132	--	--	--	--	--	--
13	76	--	--	--	--	--	--
14	98	0.015	4.5	4.4	93	0.17	0.05
15	82	--	--	--	--	--	--
16	38	0.015	4.5	4.4	93	0.17	--
17	71	0.015	4.5	4.4	93	0.17	0.05
18	143	0.015	4.5	4.4	93	0.17	0.05
19	79	--	4.5	--	--	--	--
20	70	0.015	4.5	4.4	93	0.17	0.05
21	54	0.015	4.5	4.4	93	0.17	0.05
22	17	--	--	--	--	--	--
26	53	0.015	2.5	5.5	27	0.05	0.15
28	49	--	--	--	--	--	--
29	33	0.015	2.5	5.5	27	0.05	0.15
31	54	0.015	2.5	5.2	27	0.05	0.15
32	54	0.015	2.5	5.2	27	0.05	0.15
33	156	0.015	2.5	5.2	27	0.05	0.15

TABLE C3. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	8.47	0.02	--	4.2	8	280	1.5	3
2	8.47	0.02	0.005	4.2	8	280	1.5	3
3	8.47	0.02	0.005	4.2	8	280	1.5	3
4	8.47	0.02	0.005	4.2	8	280	1.5	3
5	8.47	0.02	0.005	4.2	8	280	1.5	3
6	8.47	0.02	0.005	4.2	8	280	1.5	3
7	8.47	0.02	0.005	4.2	8	280	1.5	3
8	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--
11	8.47	0.02	0.005	5.1	7	308	2.1	2
12	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--
14	8.47	0.02	0.005	5.6	7	336	2.1	2
15	--	--	--	--	--	--	--	--
16	8.47	0.02	0.005	5.6	7	336	2.1	2
17	8.47	0.02	0.005	5.1	7	336	2.1	2
18	8.47	0.02	0.005	5.1	7	336	2.1	2
19	--	0.02	--	--	7	--	2.1	2
20	8.47	0.02	0.005	5.1	7	336	2.1	2
21	8.47	0.02	0.005	5.1	7	336	2.1	2
22	--	--	--	--	--	--	--	--
26	8.47	0.02	0.005	6.4	4	370	1.9	2
28	--	--	--	--	--	--	--	--
29	8.47	0.02	0.005	6.4	4	370	1.9	2
31	8.47	0.02	0.005	5.4	4	370	1.9	2
32	8.47	0.02	0.005	5.4	4	370	1.9	2
33	8.47	0.02	0.005	5.4	4	370	1.9	2

TABLE C4. -- Baseflow Concentrations Assigned to Runoff Events at Station 4

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100mL	TKN mg/L	NO_3+NO_2 mg/L N
1	69	0.015	3.6	3.9	1550	--	0.04
2	34	0.015	3.6	3.9	1550	--	0.04
3	84	0.015	--	2.7	1550	0.12	0.04
4	75	0.015	3.6	2.7	1550	0.12	0.04
5	75	0.015	3.6	2.7	1550	0.12	0.04
6	51	0.015	3.6	3.9	1550	0.12	0.04
7	16	0.015	3.6	3.9	1550	0.12	0.04
9	20	--	--	--	--	--	--
10	144	--	--	--	--	--	--
11	120	0.015	7.2	5.6	94	0.21	0.04
12	110	--	--	5.6	94	--	--
13	67	--	--	--	--	--	--
14	92	0.015	7.2	5.6	94	0.21	0.04
15	69	--	--	--	--	--	--
16	43	0.015	7.2	5.6	94	0.21	--
17	69	0.015	7.2	5.6	94	0.21	0.04
18	132	0.015	7.2	5.6	94	0.21	0.04
19	77	--	--	--	--	--	--
20	77	0.015	7.2	5.6	94	0.21	0.04
21	59	0.015	7.2	5.6	94	0.21	0.04
22	24	--	--	--	--	--	--
26	58	0.03	3.9	6.4	337	0.06	0.04
28	50	--	--	--	--	--	--
29	39	0.03	3.9	6.4	337	0.06	0.04
31	46	0.03	3.9	6.4	337	0.06	0.04
32	55	0.03	3.9	6.4	337	0.06	0.04
33	150	0.03	3.9	6.4	337	0.06	0.04

TABLE C4. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	8.56	0.02	--	4.9	15	294	2.5	3
2	8.56	0.02	0.005	4.9	15	294	2.5	3
3	8.56	0.02	0.005	4.9	15	294	2.5	3
4	8.56	0.02	0.005	4.9	15	294	2.5	3
5	8.56	0.02	0.005	4.9	15	294	2.5	3
6	8.56	0.02	0.005	4.9	15	294	2.5	3
7	8.56	0.02	0.005	4.9	7	294	2.5	3
9	--	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--	--
11	8.56	0.02	0.005	6.1	11	340	5.9	3
12	8.56	--	--	--	11	376	5.9	3
13	--	--	--	--	--	--	--	--
14	8.56	0.02	0.005	6.3	11	376	5.9	3
15	--	--	--	--	--	--	--	--
16	8.56	0.02	0.005	6.3	11	376	5.9	3
17	8.56	0.02	0.005	6.2	11	376	5.9	3
18	8.56	0.02	0.005	6.2	11	376	5.9	3
19	--	--	--	--	--	--	--	--
20	8.56	0.02	0.005	6.2	11	376	5.9	3
21	8.56	0.02	0.005	6.2	11	376	5.9	3
22	--	--	--	--	--	--	--	--
26	8.56	0.02	0.01	7.1	10	404	3.1	3
28	--	--	--	--	--	--	--	--
29	8.56	0.02	0.01	7.1	10	404	3.1	3
31	8.56	0.02	0.01	7.1	10	404	3.1	3
32	8.56	0.02	0.01	7.1	10	404	3.1	3
33	8.56	0.02	0.01	7.1	10	404	3.1	3

TABLE C5. -- Baseflow Concentrations Assigned to Runoff Events at Station 5

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 m/L	TKN mg/L	NO_3+NO_2 mg/L N
1	69	0.015	3.6	4.6	201	--	0.08
2	37	--	--	--	--	--	--
3	48	0.015	--	3.3	201	0.19	0.08
4	58	0.015	3.6	3.3	201	0.19	0.08
5	66	0.015	3.6	3.3	201	0.19	0.08
6	42	0.015	3.6	4.6	201	0.19	0.08
7	12	0.015	3.6	4.6	201	0.19	0.08
8	18	--	--	--	--	--	--
9	8.2	--	--	--	--	--	--
10	91	0.015	6.3	7.6	277	0.24	0.08
11	101	0.015	6.3	7.6	277	0.24	0.08
12	92	0.015	6.3	7.6	277	0.24	0.08
13	47	--	--	--	--	--	--
14	75	0.015	6.3	7.6	277	0.24	0.08
15	58	0.015	6.3	7.6	277	0.24	0.08
16	32	0.015	6.3	7.6	277	0.24	--
17	47	0.015	6.3	7.6	277	0.24	0.08
18	100	0.015	6.3	7.6	277	0.24	0.08
19	54	--	6.3	--	--	--	--
20	48	0.015	6.3	7.6	277	0.24	0.08
21	43	0.015	6.3	7.6	277	0.24	0.08
22	9.7	--	--	--	--	--	--
26	48	0.015	3.9	8.3	214	0.05	0.08
28	53	--	--	--	--	--	--
29	41	0.015	3.9	8.3	214	0.05	0.08
31	53	0.015	3.9	7.8	214	0.05	0.06
32	53	0.015	3.9	7.8	214	0.05	0.06
33	146	0.015	3.9	7.8	214	0.05	0.06

TABLE C5. -- Continued

Event No.	pH	Total mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	8.35	0.02	--	6	20	309	3.7	4
2	--	--	--	--	--	--	--	--
3	8.35	0.02	0.005	6	20	309	3.7	--
4	8.35	0.02	0.005	6	20	309	3.7	4
5	8.35	0.02	0.005	6	20	309	3.7	4
6	8.35	0.02	0.005	6	20	309	3.7	4
7	8.35	0.02	0.005	6	7	309	3.7	4
8	--	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--	--
10	8.35	0.02	0.005	8	9	407	3.2	3
11	8.35	0.02	0.005	8	9	440	3.2	3
12	8.35	0.02	0.005	8	9	440	3.2	3
13	--	--	--	--	--	--	--	--
14	8.35	0.02	0.005	8	9	440	3.2	3
15	8.35	0.02	0.005	8	9	440	3.2	3
16	8.35	0.02	0.005	8	9	440	3.2	3
17	8.35	0.02	0.005	8	9	440	3.2	3
18	8.35	0.02	0.005	8	9	440	3.2	3
19	--	0.02	--	--	9	--	3.2	3
20	8.35	0.02	0.005	8	9	440	3.2	3
21	8.35	0.02	0.005	8	9	440	3.2	3
22	--	--	--	--	--	--	--	--
26	8.35	0.02	0.005	8.8	7	425	2.9	2
28	--	--	--	--	--	--	--	--
29	8.35	0.02	0.005	8.8	7	425	2.9	2
31	8.35	0.02	0.005	8.8	7	425	2.9	2
32	8.35	0.02	0.005	8.8	7	425	2.9	2
33	8.35	0.02	0.005	8.8	7	425	2.9	2

TABLE C6. -- Baseflow Concentrations Assigned to Runoff Events at Station 6

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	1.9	--	22	64	6700	--	0.25
2	0.1	--	--	--	--	--	--
3	0.1	0.57	--	64	6700	1.08	0.25
4	0.1	0.57	22	64	6700	1.08	0.25
5	0.1	0.57	22	64	6700	1.08	0.25
6	0.1	0.57	22	64	6700	1.08	0.25
7	0.1	0.57	22	90	--	1.08	0.25
8	--	0.57	22	91	3100	1.08	0.47
9	0.1	--	--	--	--	--	--
10	0.1	0.57	22	91	--	1.08	0.47
11	0.1	--	--	--	--	--	--
12	1.1	0.57	22	91	3100	1.08	0.47
13	0.1	0.57	22	91	3100	--	0.47
14	0.1	0.57	22	91	3100	1.08	0.47
15	0.68	0.57	22	91	3100	1.08	0.47
16	0.1	0.57	22	91	3100	1.08	--
17	0.1	0.57	22	91	3100	1.08	0.47
18	0.1	0.57	22	91	3100	1.08	0.47
19	0.1	--	22	--	--	--	--
20	0.1	0.57	22	91	3100	1.08	0.47
21	0.1	0.57	22	91	3100	1.08	0.47
22	0.1	--	--	--	--	--	--
26	0.1	0.57	22	78	2800	1.08	0.67
28	0.85	--	--	--	--	--	--
29	0.1	0.57	22	78	2800	1.08	0.67
31	0.1	0.57	22	78	2800	1.08	0.67
32	0.1	0.57	22	78	2800	1.08	0.67
33	0.1	0.57	22	78	2800	1.08	0.67

APPENDIX D

Undiluted Event Mean Concentrations

TABLE C6. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	7.57	0.08	--	104	20	2265	6.4	4
2	--	--	--	--	--	--	--	--
3	7.57	0.08	0.01	112	20	2265	6.4	4
4	7.57	0.08	0.01	112	20	2265	6.4	4
5	7.57	0.08	0.01	112	20	2265	6.4	4
6	7.57	0.08	0.01	128	20	2265	6.4	4
7	7.57	0.08	0.01	128	10	2265	6.4	4
8	7.57	0.04	0.01	128	11	2430	6.4	4
9	--	--	--	--	--	--	--	--
10	7.57	0.04	0.01	140	11	2430	6.4	4
11	--	--	--	--	--	--	--	--
12	7.57	0.04	0.01	128	11	2430	6.4	4
13	7.57	0.04	0.01	128	11	2430	6.4	4
14	7.57	0.04	0.01	128	11	2430	6.4	4
15	7.57	0.04	0.01	128	11	2430	6.4	4
16	7.57	0.04	0.01	128	11	2430	6.4	4
17	7.57	0.04	0.01	128	11	2430	6.4	4
18	7.57	0.04	0.01	128	11	2430	6.4	4
19	--	0.04	--	--	11	--	6.4	4
20	7.57	0.04	0.01	128	11	2430	6.4	4
21	7.57	0.04	0.01	128	11	2430	6.4	4
22	--	--	--	--	--	--	--	--
26	7.57	0.03	0.01	158	8	2755	6.4	2
28	--	--	--	--	--	--	--	--
29	7.57	0.03	0.01	158	8	2755	6.4	2
31	7.57	0.03	0.01	158	8	2755	6.4	2
32	7.57	0.03	0.01	158	8	2755	6.4	2
33	7.57	0.03	0.01	158	8	2755	6.4	2

TABLE D1 -- Undiluted Event Mean Concentrations for Station 1

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	75	0.26	82.5	-21.5	3828	--	0.84
3	103	3.8	2.5	31.5	14708	3.55	1.12
4	90	1.17	2.5	-3.3	3700	10.21	6.02
5	82	0.98	2.5	16.4	3073	-0.56	1.33
6	32	0.02	55.0	2.5	2120	3.24	0.16
7	5.6	0.09	11.5	1.9	437	0.41	0.25
14	61	0.02	57.2	8.2	620	0.45	0.36
17	92	0.37	165.1	-0.3	5474	5.42	-0.46
18	127	1.20	358.9	-31.8	4888	0.31	-0.75
21	42	0.28	48.3	-2.8	1469	0.19	0.14
26	42	0.68	2.5	-6	250	4.3	0.13
29	13	0.08	2.5	1.6	104	0.03	0.02
31	25	-0.11	2.5	5.1	1185	0.02	0.27
32	29	0.19	2.5	6.6	1046	0.03	-0.03
33	143	-0.09	2.5	-12.5	422	1.2	-0.1

TABLE D1. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	99999*	0.25	--	9.6	85	-442	21.3	2
3	99999	0.11	.11	-1.1	375	569	26.4	2
4	99999	0.005	0.005	3.2	330	1168	0.5	237
5	99999	0.005	0.005	3.2	48	654	7	26
6	6.78	0.005	0.005	0.2	2	137	-0.7	2
7	8.13	0.01	0.01	3.6	5	191	3.4	5
14	7.95	0.15	0.03	3.3	30	190	6.3	2
17	6.77	0.08	0.01	-3.6	44	315	4.8	2
18	7.02	0.67	0.14	-1.8	81	336	7.9	2
21	8.29	0.08	0.005	1.6	21	124	17.9	2
26	7.22	0.05	0.15	-0.1	49	155	6.5	2
29	7.9	0.01	0.01	4.3	2	217	1.2	2
31	99999	0.005	0.005	11.5	2	-82	-1.4	2
32	99999	0.13	0.05	7	27	65	9.9	2
33	99999	0.11	0.01	-2.7	2	144	11.8	2

*Impossible computation because of negative values.

TABLE D2. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	7.82	2.18	--	5.6	2938	2665	624.8	251
2	7.82	0.17	0.01	9.1	176	760	116.4	40
3	7.84	2.16	0.66	1.4	3705	4608	1726.9	398
4	7.22	0.17	0.04	2.5	205	423	94.4	47
5	6.64	0.23	0.005	3.3	328	660	148.8	53
6	7.88	0.02	0.005	4.5	7	209	17.1	8
7	7.87	0.31	0.05	2.9	348	596	165.7	50
11	7.46	0.19	0.09	-8.9	120	42	38.8	2
14	7.84	0.15	0.05	2.5	176	405	64.1	16
17	7.66	0.38	0.07	-1.8	397	502	115.8	46
18	7.4	0.21	0.1	-4.2	132	206	48.1	27
20	99999*	0.02	0.01	-2.1	66	572	24.1	2
21	8.02	0.64	0.04	1.5	873	1145	326.4	70
26	7.77	0.41	0.09	0.9	578	502	188.5	57
29	7.8	0.19	0.02	4.3	217	449	93.6	23
31	7.56	0.37	0.02	3.5	563	906	284.1	60
32	7.83	0.6	0.02	3.1	812	1155	248.9	77
33	7.88	0.16	0.04	-6.1	177	140	75.2	16

*Impossible computation because of negative values.

TABLE D2. -- Undiluted Event Mean Concentrations for Station 2

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	82	0.31	276.2	10.6	55724	--	1.19
2	38	0.02	109.2	9.7	5000	--	0.86
3	116	1.76	--	8	45085	4.29	1.37
4	95	0.02	94.5	-3.1	23334	1.77	0.71
5	98	0.48	106.2	17.7	14834	0.08	1.55
6	40	0.31	24.8	5.3	6440	1.88	0.21
7	20	0.42	45.7	3.1	2706	0.73	0.6
11	127	1.96	17.1	20.5	124	2.27	0.22
14	84	0.02	23.3	7.4	10653	0.94	0.20
17	97	0.02	80.7	2.7	--	3.46	0.17
18	140	0.36	40.6	-4.5	--	1.14	0.3
20	56	0.02	10.9	-8.5	4920	-0.01	-0.03
21	38	0.1	45	1	--	1.92	0.15
26	53	0.16	75.7	1	1700	3.99	0.19
29	27	0.02	38.6	2.9	1438	0.53	0.19
31	40	0.19	51.7	4.9	14531	1.58	0.43
32	47	0.23	90.3	2.8	7733	1.51	0.17
33	155	0.2	50.3	-8.9	4479	0.73	-0.03

TABLE D2. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	7.82	2.18	--	5.6	2938	2665	624.8	251
2	7.82	0.17	0.01	9.1	176	760	116.4	40
3	7.84	2.16	0.66	1.4	3705	4608	1726.9	398
4	7.22	0.17	0.04	2.5	205	423	94.4	47
5	6.64	0.23	0.005	3.3	328	660	148.8	53
6	7.88	0.02	0.005	4.5	7	209	17.1	8
7	7.87	0.31	0.05	2.9	348	596	165.7	50
11	7.46	0.19	0.09	-8.9	120	42	38.8	2
14	7.84	0.15	0.05	2.5	176	405	64.1	16
17	7.66	0.38	0.07	-1.8	397	502	115.8	46
18	7.4	0.21	0.1	-4.2	132	206	48.1	27
20	99999*	0.02	0.01	-2.1	66	572	24.1	2
21	8.02	0.64	0.04	1.5	873	1145	326.4	70
26	7.77	0.41	0.09	0.9	578	502	188.5	57
29	7.8	0.19	0.02	4.3	217	449	93.6	23
31	7.56	0.37	0.02	3.5	563	906	284.1	60
32	7.83	0.6	0.02	3.1	812	1155	248.9	77
33	7.88	0.16	0.04	-6.1	177	140	75.2	16

*Impossible computation because of negative values.

TABLE D3. -- Undiluted Event Mean Concentrations for Station 3

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	83	0.24	232.1	9.2	78954	--	1.08
2	36	0.02	116.6	7.6	6351	--	0.77
3	78	0.78	--	5	15657	1.79	0.72
4	73	0.26	66	-0.2	5109	0.65	0.43
5	86	0.18	69.6	5.3	9800	0.26	0.87
6	50	0.17	78	6.9	20005	2.6	0.34
7	19	0.26	60.2	4.1	4952	1.51	0.82
11	143	0.02	250.5	-7.6	-63	1.25	0.17
14	98	0.37	55.9	2.3	6431	0.46	0.39
16	38	0.02	78.4	5	2709	1.39	--
17	71	0.02	69.4	2.9	11620	1.42	0.1
18	143	0.22	127.9	-5.5	30193	0.84	0.27
19	79	--	123	--	--	--	--
20	70	0.02	94.1	-2.8	8317	1.04	0.25
21	54	0.04	61.3	1.5	10704	1.88	0.22
26	53	0.18	119	5.1	2037	4.21	0.19
29	33	0.02	46.7	8.6	1974	0.83	0.24
31	54	0.09	53.5	8.6	6210	1.22	0.39
32	54	0.05	101.3	5	4432	1.16	0.17
33	156	0.49	133.8	0.7	9935	0.89	-0.24

TABLE D3. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	7.97	1.5	--	7	2121	2358	856.6	137
2	8.31	0.63	0.1	11	843	1330	360.9	107
3	8.01	0.64	0.24	2.6	933	1483	552.9	74
4	6.39	0.1	0.02	3.1	115	177	37.7	14
5	7.81	0.16	0.01	2.8	246	372	113.8	35
6	7.75	0.14	0.01	4.8	290	364	154.5	27
7	8.22	0.31	0.05	3.8	352	627	190.9	50
11	7.7	0.14	0.07	-8.1	91	-232	46.5	2
14	7.79	0.23	0.04	4.4	262	594	101.9	31
16	7.34	0.15	0.04	1.7	193	516	91.5	34
17	7.86	0.19	0.02	1.4	220	390	87.6	31
18	7.52	0.2	0.07	1.1	97	103	46.5	2
19	--	0.5	--	--	639	--	292.4	89
20	8.3	0.22	0.01	2.5	278	541	134.6	33
21	7.83	0.66	0.03	2.2	935	1290	392.6	105
26	7.81	0.46	0.04	3.8	466	749	237.3	76
29	7.86	0.18	0.005	6.1	221	706	102.6	28
31	7.44	0.26	0.03	6.4	412	681	235.5	51
32	7.96	0.53	0.02	5.4	769	1093	380.4	74
33	7.67	0.3	0.03	-1.9	300	96	114.2	41

TABLE D4. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	7.97	0.91	--	5.7	1331	1443	604.5	111
2	7.91	0.67	0.06	13.6	546	869	355	79
3	7.86	1.41	0.63	3.7	2292	2493	972.4	188
4	7.77	0.25	0.05	2.9	207	376	108.6	37
5	7.86	0.5	0.05	4.1	561	704	334.9	77
6	7.90	0.3	0.01	7.7	368	712	269.5	54
7	8.17	0.53	0.07	5.1	606	882	253.5	55
11	7.71	0.22	0.11	-0.6	152	18	60.3	23
12	7.91	--	--	--	1283	1228	750.5	153
14	7.68	0.4	0.06	4.2	445	694	182.1	51
16	99999*	1.67	0.13	6.1	2296	2446	853.1	227
17	7.91	0.42	0.04	1.4	499	614	194.2	51
18	7.58	0.46	0.1	-2.7	428	328	150.3	58
20	8.25	3.64	0.16	3.4	3846	4823	1336.4	392
21	7.93	0.66	0.05	5.2	779	1073	352	87
26	7.68	0.62	0.03	11.1	697	1084	377.3	98
29	7.82	0.41	0.03	10.4	465	797	193.5	47
31	7.59	0.06	0.05	9.4	494	693	197.9	61
32	7.80	1.13	0.03	8	1431	1699	620	141
33	7.65	0.58	0.06	-2.2	532	274	156.4	68

*Impossible computation because of negative values.

TABLE D4. -- Undiluted Event Mean Concentrations for Station 4

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	69	0.18	133.3	7.9	46014	--	0.8
2	34	0.02	200.3	11.5	10769	--	1.31
3	84	1.32	--	6.1	79986	5.25	1.25
4	75	0.06	72.6	-3.2	37340	1.34	0.55
5	75	0.11	171.7	7.5	70726	0.69	1.23
6	51	0.18	126.2	9.9	170782	2.49	0.6
7	16	0.36	72.1	5.2	7723	2.17	0.62
11	120	0.02	32.7	4.3	2014	1.89	0.38
12	110	--	--	5	21730	--	--
14	92	0.11	57.1	6	21688	1.66	0.58
16	43	0.28	335.1	7.6	11431	7.66	--
17	69	0.02	82.9	3.7	8433	2.57	0.28
18	132	0.26	106.2	-2.9	36686	1.5	0.59
20	77	0.36	377.1	1.9	113866	8.91	0.79
21	59	0.02	58.7	2.1	34015	1.97	0.27
26	58	0.25	164.5	6.1	1826	4.79	0.64
29	39	0.05	64.1	7.6	21132	1.53	0.9
31	46	0.31	103	5.6	7843	2.01	0.52
32	55	0.14	153.2	5.3	22346	2.4	0.49
33	150	0.4	148.8	5	33706	2.16	0.32

TABLE D5. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	7.92	1.62	--	4.6	2004	1887	716.2	175
3	8.11	0.81	0.1	3.8	1220	1363	351.5	--
4	7.66	0.39	0.02	3.1	370	504	122.3	56
5	8.26	0.27	0.01	2.2	421	587	111	45
6	6.73	0.25	0.005	7.8	268	413	144.6	45
7	8.03	0.5	0.05	6.3	541	793	197.9	61
10	7.85	3.12	0.2	16.4	2256	2620	834.8	297
11	8.17	0.29	0.03	-4.4	284	-185	115.3	30
12	8.06	0.4	0.11	6.3	347	56	219.3	41
14	7.83	0.32	0.03	5.3	309	503	119.6	36
15	7.39	0.48	0.11	7.4	427	397	254.4	55
16	8.62	0.41	0.04	6.6	509	684	182.6	63
17	7.88	0.25	0.03	2.5	249	349	101.8	33
18	7.61	0.39	0.09	-3	355	214	118.9	40
19	--	0.73	--	--	830	--	367.8	88
20	8.30	2.11	0.12	5.5	2393	2783	930.7	232
21	7.92	0.78	0.05	4.3	927	1170	402.1	100
26	7.45	0.62	0.04	11.6	843	1118	391.2	107
29	7.78	0.46	0.04	11	459	777	204.6	46
31	7.62	0.38	0.02	12.1	447	597	216.2	52
32	7.93	0.82	0.01	8.1	970	1210	442.6	105
33	7.91	0.48	0.08	-9.9	492	96	129.8	58

TABLE D5. -- Undiluted Event Mean Concentrations for Station 5

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	69	0.26	226.1	7.3	67892	--	0.86
3	48	0.56	--	4.5	48748	3.24	0.59
4	58	0.35	119.6	1.3	62785	2.23	0.65
5	66	0.02	79.9	4.2	8646	1.41	0.49
6	42	0.49	21.2	19.9	42047	2.4	0.35
7	12	0.37	81.2	5.9	2734	2.18	0.59
10	91	0.61	338.9	21.3	4800	10.11	1.08
11	101	0.02	58.6	2.2	6871	1.8	0.19
12	92	0.62	80.2	6.8	5380	2.41	0.41
14	75	0.06	56.3	3.1	6590	0.85	0.5
15	58	0.06	97.5	4.5	9255	0.89	6.44
16	32	0.02	86.3	6.6	7351	2.02	--
17	47	0.02	70.5	3.4	16313	1.88	0.16
18	100	0.13	85.1	-6.7	25960	1.4	0.38
19	54	--	117.7	--	--	--	--
20	48	0.27	229.5	4.1	67791	5.78	0.61
21	43	0.05	78.9	3.3	25109	3.09	0.31
26	48	0.24	170.6	13.2	3021	5.13	0.49
29	41	0.07	74.7	11.1	19026	1.29	0.8
31	53	0.11	65	10	6539	1.54	0.34
32	53	0.04	112.6	6.9	10510	1.92	0.26
33	146	0.19	110.6	-13.9	30982	2.07	0.06

TABLE D5. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	7.92	1.62	--	4.6	2004	1887	716.2	175
3	8.11	0.81	0.1	3.8	1220	1363	351.5	--
4	7.66	0.39	0.02	3.1	370	504	122.3	56
5	8.26	0.27	0.01	2.2	421	587	111	45
6	6.73	0.25	0.005	7.8	268	413	144.6	45
7	8.03	0.5	0.05	6.3	541	793	197.9	61
10	7.85	3.12	0.2	16.4	2256	2620	834.8	297
11	8.17	0.29	0.03	-4.4	284	-185	115.3	30
12	8.06	0.4	0.11	6.3	347	56	219.3	41
14	7.83	0.32	0.03	5.3	309	503	119.6	36
15	7.39	0.48	0.11	7.4	427	397	254.4	55
16	8.62	0.41	0.04	6.6	509	684	182.6	63
17	7.88	0.25	0.03	2.5	249	349	101.8	33
18	7.61	0.39	0.09	-3	355	214	118.9	40
19	--	0.73	--	--	830	--	367.8	88
20	8.30	2.11	0.12	5.5	2393	2783	930.7	232
21	7.92	0.78	0.05	4.3	927	1170	402.1	100
26	7.45	0.62	0.04	11.6	843	1118	391.2	107
29	7.78	0.46	0.04	11	459	777	204.6	46
31	7.62	0.38	0.02	12.1	447	597	216.2	52
32	7.93	0.82	0.01	8.1	970	1210	442.6	105
33	7.91	0.48	0.08	-9.9	492	96	129.8	58

TABLE D6. -- Undiluted Event Mean Concentrations for Station 6

Event No.	Base Flow cfs	NH_3 mg/L	COD mg/L	Cl^- mg/L	Fecal Coliforms No./100 mL	TKN mg/L	NO_3+NO_2 mg/L N
1	1.9	--	367.2	2.3	28670	--	0.67
3	0.1	1	--	8.5	197956	9.44	0.81
4	0.1	0.08	128.4	2.1	95149	2.72	0.46
5	0.1	0.08	128.4	5.8	47552	3.13	0.79
6	0.1	0.59	167.8	6.1	95712	3.96	0.35
7	0.1	0.4	92.2	3.3	--	2.2	0.62
10	0.1	0.68	598.7	29.4	--	6.75	1.14
12	1.1	0.01	170.7	4	10422	4.03	0.3
13	0.1	0.16	131.5	10.2	9183	--	0.43
14	0.1	0.15	110.3	5.8	10027	3.01	0.41
15	0.68	-0.02	166.4	4.2	16902	2.06	0.63
16	0.1	0.21	352.7	6.8	15097	7.65	--
17	0.1	0.48	228.8	5.5	41330	6.85	0.6
18	0.1	0.19	180.3	5.3	58454	3.72	0.84
19	0.1	--	277	--	--	--	--
20	0.1	0.21	258.2	3	27126	6.13	0.62
21	0.1	0.14	149.2	3.4	37064	5.81	0.38
26	0.1	0.19	249.9	8.3	4005	2.76	0.46
29	0.1	0.13	87.2	6.4	21054	1.7	0.41
31	0.1	0.13	140	5.3	20145	1.81	0.4
32	0.1	0.15	250.2	5.1	36176	4.92	0.34
33	0.1	0.21	267.2	9.2	38323	4.43	0.5

TABLE D6. -- Continued

Event No.	pH	Total P mg/L	Diss. P mg/L	Na mg/L	SS mg/L	Total Residue mg/L	Turbidity NTU	VSS mg/L
1	8.02	6.94	--	4.9	11578	11177	3570.9	863
3	7.85	2.87	0.23	13.4	6151	6260	1608	464
4	7.99	1.16	0.12	4.8	1793	2037	557.2	187
5	7.96	0.5	0.05	6.4	654	790	263.5	109
6	7.33	1.79	0.03	7	3772	3891	815.6	336
7	8.27	0.72	0.12	2.6	1124	1347	401.3	100
10	7.67	2.43	0.18	31.2	6694	8288	2661.6	574
12	8.45	0.18	0.08	-0.4	2184	2441	1013	208
13	8.14	0.54	0.06	12.1	823	1163	395.3	91
14	7.95	1.04	0.07	7.2	1486	1988	552.1	122
15	7.84	0.82	0.05	2.1	1061	1200	374	107
16	8.17	3.33	0.06	10.7	4254	4960	1512.1	363
17	7.96	2.13	0.16	7.2	2804	3086	907.8	237
18	7.80	1.43	0.09	8.1	1694	2087	554.5	163
19	--	4.15	--	--	4628	--	1606.2	375
20	8.34	3.32	0.07	5.4	4323	5385	1407.3	362
21	8.08	3.14	0.05	4.2	3306	4023	1202.2	255
26	7.85	0.78	0.09	13.3	1887	2810	1003.8	311
29	7.83	1	0.09	7.7	1324	1597	501.5	116
31	7.85	1.07	0.06	7.4	1654	1883	655.4	143
32	7.90	2.58	0.07	7.4	3941	4188	1306.8	317
33	7.71	2	0.1	14.1	2371	2689	706.4	223

APPENDIX E

Runoff Loads

TABLE E1. -- Runoff Loads at Station 1

Event No.*	NH_3 lb	COD lb	Cl^- lb	TKN lb	Total Lead, lb	NO_3+NO_2 lb
1	1	417	-109	--	--	4
3	26	17	212	24	--	8
4	2	4	-6	18	--	11
5	7	17	110	-4	--	9
6	--	111	5	7	--	--
7	5	633	107	22	--	14
14	3	10,457	1,494	83	0.91	67
17	2	1,102	-2	36	0.03	-3
18	6	1,913	-170	2	0.03	-4
21	15	2,582	-150	10	0.27	7
26	5	18	-43	31	0.65	1
29	2	64	39	1	0.13	1
31	--	3	6	--	0.01	--
32	3	21	55	--	0.04	0
33	2	14	-69	7	0.03	-1

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E1. -- Continued

Event No.*	Total P, lb	Dis. P lb	Na lb	SS lb	VSS lb	Tot. Res. lb
1	1	--	48	429	10	-2,232
3	1	1	-8	2,526	13	3,832
4	--	--	6	592	425	2,097
5	--	--	22	323	172	4,399
6	--	--	--	4	4	276
7	--	--	196	262	262	10,498
14	27	5	603	5,551	366	34,657
17	1	--	-24	297	13	2,102
18	4	1	-9	433	11	1,789
21	4	--	84	1,138	107	6,632
26	--	1	0	357	15	1,129
29	--	--	110	51	51	5,535
31	--	--	13	2	2	-92
32	1	--	58	222	17	540
33	1	--	-15	11	11	793

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E2. -- Runoff Loads at Station 2

Event No.*	NH_3 lb	COD lb	Cl^- lb	TKN lb	Total Lead, lb	NO_3+NO_2 lb
1	9	7,811	299	--	--	34
2	--	588	52	--	--	5
3	108	--	491	263	--	84
4	--	2,227	-74	42	--	17
5	12	2,574	428	2	--	37
6	2	176	37	13	--	2
7	88	9,464	642	151	--	125
11	21	184	221	24	0.05	2
14	7	10,655	3,368	430	2.29	93
17	--	2,462	82	106	3.23	5
18	10	1,167	-131	33	0.14	9
20	--	72	-56	0	0.03	0
21	37	17,069	369	728	13.74	58
26	6	2,650	35	140	3.10	7
29	2	3,929	298	54	2.46	19
31	3	812	77	25	1.05	7
32	15	5,811	183	97	5.34	11
33	3	847	-149	12	0.81	-1

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E2. -- Continued

Event No.*	Total P, lb	Dis. P lb	Na lb	SS lb	VSS lb	Tot. Res. lb
1	62	--	158	83,062	7,083	75,341
2	1	--	49	946	214	4,095
3	133	41	84	226,970	24,382	282,268
4	4	1	60	4,830	1,107	9,967
5	6	--	80	7,940	1,281	15,986
6	--	--	32	49	60	1,475
7	64	11	599	72,110	10,372	123,460
11	2	1	-96	1,294	22	447
14	71	21	1,158	80,726	7,514	185,404
17	12	2	-53	12,118	1,414	15,315
18	6	3	-120	3,796	770	5,933
20	--	--	-14	434	13	3,765
21	245	16	581	331,258	26,702	434,391
26	14	3	32	20,244	1,979	17,559
29	19	2	442	22,057	2,369	45,756
31	6	--	55	8,848	940	14,227
32	39	1	202	52,229	4,986	74,329
33	3	1	-103	2,976	276	2,360

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E3. -- Runoff Loads at Station 3

Event No.*	NH_3 lb	COD lb	Cl^- lb	TKN lb	Total Lead, lb	NO_3+NO_2 lb
1	8	7,969	314	--	--	37
2	--	733	48	--	--	5
3	73	--	465	167	--	67
4	10	2,505	-7	25	--	16
5	6	2,343	179	9	--	29
6	2	919	81	31	--	4
7	82	18,650	1,259	467	--	255
11	--	5,481	-166	27	0.11	4
14	219	32,898	1,351	271	2.94	231
16	--	441	28	8	0.21	--
17	1	5,278	223	108	1.31	8
18	12	6,963	-298	46	0.27	15
19	--	5,984	--	--	--	--
20	--	1,525	-45	17	0.50	4
21	20	32,129	798	986	14.53	114
26	15	9,814	418	347	8.31	16
29	3	8,842	1,632	157	8.82	45
31	2	924	149	21	0.67	7
32	5	10,094	497	115	7.91	17
33	12	3,148	17	21	2.09	-6

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E2. -- Continued

Event No.*	Total P, lb	Dis. P lb	Na lb	SS lb	VSS lb	Tot. Res. lb
1	62	--	158	83,062	7,083	75,341
2	1	--	49	946	214	4,095
3	133	41	84	226,970	24,382	282,268
4	4	1	60	4,830	1,107	9,967
5	6	--	80	7,940	1,281	15,986
6	--	--	32	49	60	1,475
7	64	11	599	72,110	10,372	123,460
11	2	1	-96	1,294	22	447
14	71	21	1,158	80,726	7,514	185,404
17	12	2	-53	12,118	1,414	15,315
18	6	3	-120	3,796	770	5,933
20	--	--	-14	434	13	3,765
21	245	16	581	331,258	26,702	434,391
26	14	3	32	20,244	1,979	17,559
29	19	2	442	22,057	2,369	45,756
31	6	--	55	8,848	940	14,227
32	39	1	202	52,229	4,986	74,329
33	3	1	-103	2,976	276	2,360

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E3. -- Continued

Event No.*	Total P, lb	Dis. P lb	Na lb	SS lb	VSS lb	Tot. Res. lb
1	51	--	239	72,817	4,711	80,974
2	4	1	69	5,299	675	8,359
3	60	22	247	87,116	6,908	138,398
4	4	1	116	4,347	547	6,720
5	5	--	95	8,292	1,181	12,510
6	2	--	57	3,416	318	4,288
7	97	15	1,182	109,112	15,542	194,133
11	3	1	-177	1,991	44	-5,076
14	136	27	2,601	154,586	18,241	349,935
16	1	--	10	1,089	192	2,904
17	15	1	109	16,736	2,387	29,651
18	11	4	58	5,267	109	5,587
19	25	--	--	31,088	4,313	--
20	4	--	41	4,511	530	8,766
21	344	15	1,165	490,313	55,032	676,288
26	38	3	312	38,404	6,271	61,762
29	33	1	1,146	41,781	5,301	133,723
31	5	1	110	7,119	874	11,764
32	53	2	538	76,618	7,398	108,850
33	7	1	-44	7,062	967	2,263

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E4. -- Runoff Loads at Station 4

Event No.*	NH_3 lb	COD lb	Cl^- lb	TKN lb	Total Lead, lb	NO_3+NO_2 lb
1	15	11,516	681	--	--	69
2	--	3,213	184	--	--	21
3	188	--	870	751	--	179
4	4	4,511	-201	83	--	34
5	7	10,660	466	43	--	76
6	4	2,973	234	59	--	14
7	162	32,829	2,352	989	--	281
11	1	1,259	164	73	1.48	14
12	--	--	117	--	--	--
14	91	47,868	5,049	1,389	30.56	491
16	10	11,932	272	273	15.10	--
17	1	8,060	359	250	6.27	27
18	16	6,714	-183	95	5.92	38
20	71	74,770	379	1,766	92.34	157
21	13	50,620	1,776	1,697	34.86	235
26	38	24,363	897	709	40.08	95
29	15	21,674	2,572	518	31.64	303
31	16	5,314	291	104	7.06	27
32	19	20,422	702	320	28.60	66
33	14	5,019	169	73	6.61	11

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E4. -- Continued

Event No.*	Total P, lb	Dis. P lb	Na lb	SS lb	VSS lb	Tot. Res. lb
1	79	--	489	114,981	9,596	124,670
2	11	1	218	8,768	1,266	13,940
3	202	90	530	327,815	26,881	356,634
4	15	3	181	12,879	2,295	23,354
5	31	3	252	34,843	4,755	43,735
6	7	--	181	8,667	1,274	16,773
7	240	31	2,335	275,710	24,995	401,594
11	9	4	-24	5,850	891	682
12	--	--	--	30,086	3,588	28,796
14	333	48	3,527	373,029	42,939	582,531
16	60	5	216	81,752	8,090	87,087
17	41	4	140	48,513	4,920	59,705
18	29	6	-168	27,086	3,693	20,736
20	721	33	665	762,514	77,658	956,119
21	569	46	4,526	672,102	75,429	925,863
26	92	4	1,639	103,162	14,496	160,493
29	139	8	3,519	157,185	15,735	269,701
31	26	3	484	25,489	3,162	35,757
32	151	4	1,073	190,795	18,767	226,469
33	20	2	-75	17,939	2,301	9,229

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E5. -- Runoff Loads at Station 5

Event No.*	NH_3 lb	COD lb	Cl^- lb	TKN lb	Total Lead, lb	NO_3+NO_2 lb
1	24	21,300	690	--	--	81
3	71	--	563	407	--	74
4	18	6,239	67	116	--	34
5	1	3,893	206	69	--	24
6	10	441	415	50	--	7
7	193	41,906	3,058	1,128	--	303
10	53	29,455	1,847	879	58.62	94
11	1	2,470	93	76	0.21	8
12	23	2,956	250	89	0.95	15
14	58	54,986	2,997	830	30.41	486
15	7	10,519	489	95	5.51	694
16	1	3,437	262	80	2.26	--
17	1	6,577	319	175	4.91	15
18	10	6,228	-490	103	3.04	28
19	--	10,342	--	--	--	--
20	84	70,323	1,268	1,770	93.29	188
21	46	78,421	3,297	3,064	78.76	305
26	40	28,411	2,193	854	40.34	81
29	26	29,155	4,332	502	31.25	313
31	6	3,357	517	80	4.69	17
32	6	15,610	958	266	23.63	35
33	7	3,796	-479	71	4.69	2

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E5. -- Continued

Event No.*	Total P, lb	Dis. P lb	Na lb	SS lb	VSS lb	Tot. Res. lb
1	152	--	437	188,771	16,500	177,699
3	102	12	479	153,339	--	171,226
4	21	1	163	19,317	2,905	26,307
5	13	--	109	20,477	2,176	28,607
6	5	--	163	5,583	929	8,609
7	261	28	3,269	279,509	31,646	409,277
10	271	18	1,425	196,086	25,815	227,713
11	12	1	-185	11,969	1,263	-7,814
12	15	4	233	12,795	1,495	2,070
14	309	30	5,208	301,455	35,259	490,898
15	52	12	797	46,026	5,955	42,821
16	16	1	261	20,279	2,507	27,239
17	23	3	231	23,234	3,124	32,543
18	28	6	-218	25,966	2,896	15,649
19	64	--	--	72,890	7,728	--
20	647	36	1,676	733,178	71,066	852,594
21	770	49	4,320	920,668	99,281	1,162,452
26	103	7	1,936	140,364	17,864	186,152
29	180	16	4,298	179,094	18,015	303,241
31	20	1	626	23,065	2,674	30,788
32	114	2	1,121	134,399	14,582	167,673
33	16	3	-340	16,903	1,978	3,309

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E6. -- Runoff Loads at Station 6

Event No.*	NH_3 lb	COD lb	Cl^- lb	TKN lb	Total Lead, lb	NO_3+NO_2 lb
1	--	12,374	78	--	72.92	23
3	22	--	190	211	10.32	18
4	1	1,642	27	35	2.72	6
5	1	1,227	56	30	2.23	8
6	4	1,040	38	25	1.77	2
7	53	12,364	445	295	17.48	83
10	10	8,741	429	98	18.11	17
12	--	1,805	43	43	3.81	3
13	2	1,576	122	--	0.97	5
14	29	21,583	1,129	588	15.71	80
15	-1	5,083	129	63	2.93	19
16	3	5,110	99	111	--	--
17	5	2,608	62	78	--	7
18	3	2,448	72	51	2.19	11
19	--	7,915	--	--	--	--
20	5	5,964	70	141	15.32	14
21	38	41,126	947	1,601	71.78	105
26	9	11,981	400	132	4.57	22
29	18	12,326	903	241	22.40	58
31	3	3,427	130	44	4.94	10
32	6	10,081	206	198	17.90	14
33	2	2,288	79	38	4.26	4

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E6. -- Continued

Event No.*	Total P, lb	Dis. P lb	Na lb	SS lb	VSS lb	Tot. Res. lb
1	234	--	164	390,120	29,088	376,605
3	64	5	299	137,331	10,367	139,771
4	15	2	61	22,934	2,397	26,055
5	5	--	61	6,245	1,046	7,550
6	11	--	43	22,384	2,085	24,122
7	97	16	348	150,625	13,447	180,579
10	35	3	456	97,744	8,376	121,007
12	2	1	-4	23,094	2,198	25,816
13	6	1	145	9,863	1,093	13,932
14	204	14	1,401	290,606	23,953	388,909
15	25	2	63	32,388	3,259	36,630
16	48	1	154	61,646	5,259	71,879
17	24	2	82	31,960	2,701	35,169
18	19	1	110	22,995	2,217	28,336
19	118	--	--	132,240	10,728	--
20	77	2	124	99,828	8,357	124,375
21	864	14	1,149	911,087	70,401	1,108,618
26	38	4	640	90,490	14,921	134,746
29	142	13	1,083	187,151	16,446	225,705
31	26	1	182	40,480	3,505	46,086
32	104	3	298	158,775	12,758	168,720
33	17	1	121	20,302	1,909	23,024

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E7. -- Runoff Loads at Station 56

Event No.*	NH_3 lb	COD lb	Cl^- lb	TKN lb	Total Lead, lb	NO_3+NO_2 lb
1	--	33,673	768	--	--	103
3	93	--	753	618	--	92
4	19	7,881	94	151	--	40
5	2	5,120	262	99	--	31
6	14	1,482	453	74	--	9
7	246	54,270	3,503	1,423	--	386
10	63	38,197	2,276	977	76.72	110
12	23	4,761	292	131	4.76	18
14	87	76,569	4,125	1,418	46.11	566
15	6	15,601	618	158	8.44	714
16	4	8,547	360	191	--	--
17	7	9,185	381	253	--	21
18	12	8,676	-418	153	5.23	39
19	--	18,257	--	--	--	--
20	89	76,287	1,338	1,912	108.62	202
21	84	119,546	4,244	4,665	150.54	410
26	50	40,392	2,593	986	44.91	103
29	44	41,481	5,235	743	53.65	371
31	9	6,784	646	124	9.62	27
32	12	25,691	1,164	464	41.53	49
33	8	6,084	-400	109	8.94	6

*Events which are not included were either not sampled at this station or had negligible runoff volumes.

TABLE E7. -- Continued

Event No.*	Total P, lb	Dis. P lb	Na lb	SS lb	VSS lb	Tot. Res. lb
1	386	--	601	578,891	45,588	554,304
3	166	17	778	290,669	--	310,998
4	35	3	225	42,252	5,302	52,362
5	18	1	170	26,722	3,221	36,157
6	16	--	206	28,966	3,014	32,731
7	358	44	3,617	430,133	45,093	589,857
10	306	20	1,881	293,830	34,190	348,720
12	16	5	229	35,889	3,694	27,886
14	513	44	6,609	592,061	59,212	879,807
15	77	14	860	78,414	9,214	79,451
16	65	2	415	81,926	7,765	99,119
17	47	5	313	55,193	5,825	67,713
18	48	8	-107	48,961	5,113	43,985
19	183	--	--	205,131	18,456	--
20	723	38	1,800	833,006	79,423	976,969
21	1,634	62	5,469	1,831,755	169,681	2,271,070
26	140	12	2,576	230,854	32,785	320,898
29	322	29	5,380	366,244	34,461	528,945
31	46	2	808	63,546	6,178	76,874
32	218	5	1,419	293,174	27,340	336,393
33	33	4	-219	37,205	3,887	26,333

*Events which are not included were either not sampled at this station or had negligible runoff volumes.